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# DETERMINATION OF TENSILE, COMPRESSIVE, BEARING AND SHEAR PROPERTIES OF SHEET STEELS AT ELEVATED TEMPERATURES

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*NOVEMBER 1958*

WRIGHT AIR DEVELOPMENT CENTER

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# DETERMINATION OF TENSILE, COMPRESSIVE, BEARING AND SHEAR PROPERTIES OF SHEET STEELS AT ELEVATED TEMPERATURES

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*NOVEMBER 1958*

MATERIALS LABORATORY
CONTRACT NO. AF 33(616)-3876
PROJECT NO. 7360

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
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# FOREWORD

This report was prepared by Southern Research Institute under USAF Contract No. AF 33(616)-3876. This contract was initiated under Project No. 7360, "Materials Analysis and Evaluation Techniques," Task No. 73605, "Design Data for Metals". It was administered under the direction of the Materials Laboratory, Directorate of Laboratories, Wright Air Development Center, with Mr. A. Brisbane acting as project engineer.

This report covers work conducted from January 1957 to May 1958.

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( pp) ( fig.) ( tbls.) ( ref.)


## ABSTRACT

The tensile, compressive, bearing, and shear properties of the following sheet metals were determined at various temperatures after exposure times of from 1/2 hour to 1000 hours at the test temperature:

1. A-286 austenitic alloy, quenched and tempered
2. 17-7 PH stainless steel, RH 950 condition
3. Thermold J alloy steel, quenched and tempered
4. Type 420 stainless steel, quenched and tempered
5. Type 422 stainless steel, quenched and tempered
6. 17-22 A (S) alloy steel, quenched and tempered

The A-286 alloy was tested over a temperature range from 75° F to 1200° F, the Thermold J from 75° F to 1100° F, and the other alloys from 75° F to 1000° F.

In all of the test alloys, the strength properties and moduli of elasticity decreased with increasing temperatures. The strength properties of the Thermold J, Type 420, Type 422, and 17-22 A (S) tended to decrease by varying amounts with increasing exposure times at the higher test temperatures. These decreases in strength are believed to be associated with structural changes produced by tempering. At lower temperatures, the properties of these materials did not vary significantly with exposure time, indicating that the structures were stable at those temperatures. The strength properties of the A-286 alloy and the 17-7 PH (RH 950) stainless varied somewhat erratically with increasing exposure times at the higher test temperatures as a result, probably, of aging phenomena in both of these precipitation-hardening alloys.

The simple ratio relationships between various properties under equivalent test conditions were approximately equal in magnitude and in consistency to those previously determined for other materials and reported in WADC Technical Report 56-340. For the entire ranges of materials and conditions used in this work, the consistency of the various property relationships ranged from ± 17% to ± 71%. Precise data on the mechanical properties of aircraft-structural materials can be obtained only by testing under the desired condition.


## PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Richard R Kennedy

RICHARD R. KENNEDY
Chief, Metals Branch
Materials Laboratory

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# DETERMINATION OF TENSILE, COMPRESSIVE, BEARING AND SHEAR PROPERTIES OF SHEET STEELS AT ELEVATED TEMPERATURES

## SECTION I. INTRODUCTION

### 1.1 Purpose of the Program

Many alloys at certain temperature levels are not susceptible to structural changes. Elevated-temperature properties under these conditions are determined by the magnitude of the temperature alone. Under alloying and temperature conditions that do bring about structural changes, such as precipitation and grain growth, the elevated-temperature properties of metals are functions of both temperature and time at temperature. Design data based on elevated temperature tests with the standard exposure time of 30 minutes are not necessarily applicable to aircraft parts that will be used for extended periods of time at elevated temperatures.

The purpose of this investigation was to determine the effects of exposure times up to 1000 hours at test temperature on the elevated-temperature tensile, compressive, bearing, and shear properties of six aircraft-structural sheet steels.

### 1.2 History of the Test Program

Under Contracts AF 33(616)-2741 and AF 33(616)-3224, Southern Research Institute has carried out a previous program on the determination of tensile, compressive, bearing, and shear properties of ferrous and non-ferrous structural sheet metals at elevated temperatures. The results of the program were reported in WADC Technical Report 56-340, which was released for publication in October 1956. The basic test equipment and methods used in this present project were developed during that first program and were described in detail in the report.

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[1] Manuscript released by authors Sept 1958 for publication as a WADC Technical Report

## SECTION II. SCOPE

### 2.1 Test Materials

The test metals and the heat-treated conditions in which they were tested were as follows:

1. A-286 austenitic age-hardening alloy--1800° F 1 hr argon atmosphere, O. Q., 1325° F 16 hr, A. C.

2. 17-7 PH stainless steel—RH 950 condition—1750° F 10 min argon atmosphere, A. C., -100° F 8 hr, 950° F 1 hr, A. C.

3. Thermold J alloy steel—1850° F 15 min argon atmosphere, A. C., 1000° F 2 hr, A. C., 1000° F 2 hr, A. C.

4. Type 420 stainless steel—1300° F 15 min argon atmosphere, O. Q., 900° F 3 hr, A. C.

5. Type 422 stainless steel—1900° F 15 min argon atmosphere, O. Q., 1000° F 2 hr, A. C.

6. 17-22 A (S) low-alloy steel—1750° F 15 min argon atmosphere, O. Q., 1300° F 1 hr, A. C.

For each test metal all test specimens were heat treated simultaneously.

The mechanical properties and chemical analyses, furnished by the manufacturers of these materials, are shown in Tables 1 and 2. Two thicknesses of each material—0.062 in. and 3/16 in.—were required to provide for the various specimen designs that were used in this investigation. As shown in Tables 1 and 2, both thicknesses were obtained from the same heats of Thermold J, Type 422, and 17-22 A (S), whereas it was necessary to obtain the two thicknesses from different heats of A-286, 17-7 PH, and Type 420.

### 2.2 Test Conditions

Test temperatures ranged from room temperature to 1200° F for the A-286 alloy, to 1100° F for the Thermold J tool steel, and to 1000° F for the other test materials. Exposure times of the test specimens at the test temperatures prior to testing ranged from 1/2 hour to 1000 hours. The range of exposure times was the same for all of the test materials. An

Table 1

Mechanical Properties of Test Materials Reported by Manufacturers

| Material | Heat No. | Form | Condition[1] | YS, psi | UTS, psi | % Elong. | Hardness |
|---|---|---|---|---|---|---|---|
| A-286 | B-10205 | 0.062-in. sheet | b | 86,400 | 152,700 | 23 | 28.0 RC |
| A-286 | C-9643 | 3/16-in. plate | b | 70,300 | 146,100 | 25 | 30.5 RC |
| 17-7 PH | 56788 | 0.062-in. sheet | a | 48,600 | 121,000 | 42.0 | 87.5 RB |
| | | | d | 177,200 | 193,200 | 9.0 | 42.0 RC |
| 17-7 PH | 55464 | 3/16-in. plate | a | 37,600 | 116,800 | 39.0 | 87.0 RB |
| | | | d | 156,000 | 189,500 | 11.0 | 41.5 RC |
| Thermold J | D-19256 | 0.062-in. sheet | c | | | | 57.0 RC |
| Thermold J | D-19256 | 3/16-in. plate | c | | | | 57.0 RC |
| Type 420 | 143563 | 0.062-in. sheet | a | | | | |
| Type 420 | 143564 | 3/16-in. plate | a | | | | |
| Type 422 | E-142761 | 0.062-in. sheet | a | | | | |
| Type 422 | E-142761 | 3/16-in. plate | a | | | | |
| 17-22 A (S) | D-19178 | 0.062-in. sheet | a | | | | 79/82 RB |
| 17-22 A (S) | D-19178 | 3/16-in. plate | a | | | | 83/84 RB |

1. Condition
   a. Hot rolled, annealed, and pickled
   b. Heat treatment — 1800° F 1 hr, A. C., 1300° F 16 hr, A. C.
   c. Heat treatment — 1850° F 5 min, A. C., 900° F 2 hr, A. C.
   d. TH-1050, 1400° F 90 min, A. C. to R. T. and W. C. to 60° F, 1050° F 90 min, A. C.

## Table 2

Chemical Analysis of Test Materials Reported by Manufacturers

| Material | Heat No. | C | Mn | Si | S | P | Cr | Ni | Mo | V | Ti | Al | Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Composition-Percent | | | | | | | | | | | |
| A-286 | B 10205[1] | 0.033 | 1.52 | 0.56 | 0.005 | 0.016 | 15.35 | 25.35 | 1.27 | 0.24 | 2.02 | 0.22 | Rem |
| A-286 | C 9643[1] | 0.044 | 1.48 | 0.70 | 0.005 | 0.024 | 15.46 | 24.47 | 1.24 | 0.23 | 2.08 | 0.25 | Rem |
| Thermold J | D 19256[1] | 0.520 | 0.30 | 1.09 | 0.005 | 0.017 | 5.05 | 1.53 | 1.40 | 1.05 | | | Rem |
| 17-7 PH | 55464[2] | 0.088 | 0.59 | 0.47 | 0.016 | 0.018 | 17.62 | 7.17 | | | | 1.23 | Rem |
| 17-7 PH | 56788[2] | 0.079 | 0.71 | 0.36 | 0.009 | 0.019 | 17.41 | 7.27 | | | | 1.22 | Rem |

| Material | Heat No. | C | Mn | Si | S | P | Cr | Ni | Mo | V | W | Fe |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type 422 | E 142761[3] | 0.22 | 0.68 | 0.36 | 0.018 | 0.019 | 11.71 | 0.69 | 0.94 | 0.26 | 0.93 | Rem |
| Type 420 | E 143564[3] | 0.33 | 0.40 | 0.40 | 0.013 | 0.013 | 13.42 | | | | | Rem |
| Type 420 | 143563[3] | 0.30 | 0.51 | 0.43 | 0.008 | 0.018 | 13.25 | | | | | Rem |
| 17-22 A (S)[4] | D19178[1] | 0.30 | 0.51 | 0.55 | 0.008 | 0.016 | 1.19 | | 0.50 | 0.23 | | Rem |

1. Produced by Universal-Cyclops
2. Produced by Armco Steel Corp.
3. Produced by Crucible Steel Co.
4. This alloy designation is used by Timken Roller Bearing Co. who developed the alloy. Universal-Cyclops designated the same alloy as 14 MV

outline of the test temperatures and exposure times for the various materials is shown in Table 3.

For the 1/2-hour exposure times, each specimen was heated, aged, and tested in one continuous operation in the testing furnace. The longer exposure times were carried out in separate aging furnaces. After the specimens were exposed in the aging furnaces at the required temperature for ten minutes less than the nominal exposure times shown in Table 3, they were air cooled. During the tests, the specimens were reheated in about 20 minutes in the testing furnace to the same exposure temperature, held for ten minutes, and then tested.

## 2.3 Properties Measured

Tensile, compressive, and bearing properties were determined on the 0.062-in.-thick sheet materials, whereas shear properties were determined on specimens machined from the 3/16-in. plate. Tensile tests were also conducted on the 3/16-in. plate in order to provide a direct comparison of tensile strength between the two thicknesses of each test metal.

In tensile tests on 0.062-in. sheet, the complete stress-strain curves were recorded, and the following properties were determined: 0.2%-offset yield strength, ultimate tensile strength, modulus of elasticity, rupture strength based on the original specimen cross-sectional area, rupture strength based on the final specimen cross-sectional area, and total elongtion. In tensile tests on 3/16-in. plate, only the ultimate tensile strength was determined.

Compressive stress-strain curves were recorded through the 0.2%-offset yield point, and the following compression properties were determined: 0.2%-offset yield strength, modulus of elasticity, and tangent modulus at various stress levels up to the 0.2%-offset yield strength.

In the bearing tests, stress-deformation curves were recorded through the yield point. The bearing yield strength and ultimate bearing strength were reported for each bearing test. The bearing specimens were loaded in tension through two clevis pins that fit snugly in bearing holes at opposite ends of the specimens. The deformation recorded in these tests was that which occurred in the smaller bearing hole, which was 1/4-in. in diameter. This deformation was equivalent to the relative displacement of the center line of the 1/4-in. bearing pin with respect to the original center line of the 1/4-in. bearing hole. Bearing failures consisted of fractures of the test specimens adjacent to this bearing pin. Bearing yield strength was defined as the stress that produces a permanent deformation of 0.05-in. which is equivalent to 2% of

## Table 3

**Test Materials, Test Temperatures, and Exposure Times for Tensile, Compression, Bearing, and Shear Tests**

| Material, Sheet[1] | Heat-Treatment | Test Temperature, °F | Exposure Time,[2] Hrs |
|---|---|---|---|
| 17-7 PH (RH 950) Stainless steel | 1750° F, 10 min, A. C.<br>-100° F, 8 hr<br>950° F, 1 hr, A. C. | RT, 600, 800, 1000 | 1/2, 10, 100, 1000 |
| Thermold J Alloy steel | 1850° F, 15 min, A. C.<br>1000° F, 2 hr, A. C.<br>1000° F, 2 hr, A. C. | RT, 600, 800, 1000, 1100 | 1/2, 10, 100, 1000 |
| Type 420 Stainless steel | 1800° F, 15 min, O. Q.<br>900° F, 3 hr, A. C. | RT, 400, 600, 800, 1000 | 1/2, 10, 100, 1000 |
| Type 422 Stainless steel | 1900° F, 15 min, O. Q.<br>1000° F, 2 hr, A. C. | RT, 400, 600, 800, 1000 | 1/2, 10, 100, 1000 |
| 17-22 A (S) Low-alloy steel | 1750° F, 15 min, O. Q.<br>1300° F, 1 hr, A. C. | RT, 400, 600, 800, 1000 | 1/2, 10, 100, 1000 |
| A-286 austenitic age-hardening alloy | 1800° F, 1 hr, O. Q.<br>1325° F, 16 hr, A. C. | RT, 600, 800, 1000, 1100, 1200 | 1/2, 10, 100, 1000 |

1. Thickness of 0.062-in. and 3/16-in. for tensile tests, 0.062-in. for compressive and bearing tests, and 0.125 diameter machined from 3/16-in. plate for shear tests.
2. Time of exposure of test specimens to elevated temperatures prior to testing at the same elevated temperatures.

the bearing hole diameter. For the calculation of bearing stresses from load measurements, the bearing area was considered to be the area of contact between the 1/4-in. bearing pin and the bearing hole projected onto a plane perpendicular to the direction of loading. This area is equivalent to the product of the diameter of the 1/4-in. bearing pin and the thickness of the bearing specimens.

Ultimate shear strength was the only property measured in the shear tests. No deformation measurements were made in these tests. The type of shear-testing fixture used produced shear failures across two cross sections of the pin-type specimens. Shear strength values, therefore, were determined by dividing the ultimate load by twice the cross-sectional area of the specimens.

Hardness determinations were made on all test specimens at room temperature after the completion of the tests.

## SECTION III. PREPARATION OF TEST SPECIMENS

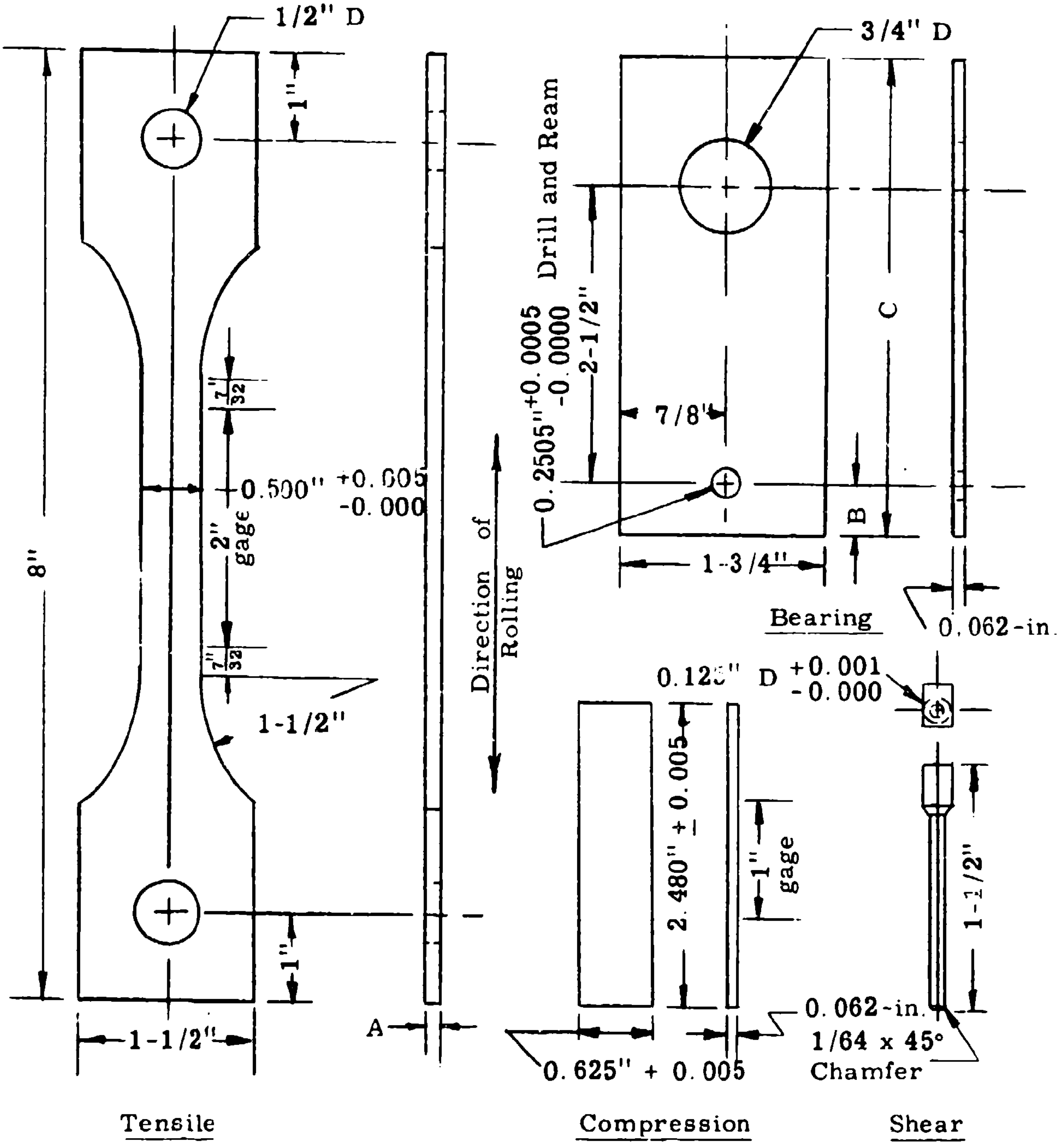
The dimensions of the various types of test specimens are shown in Fig. 1. Two sets of bearing specimens with edge-distance to hole-diameter ratios of 1.5 to 1 and of 2.0 to 1 were tested at all combinations of temperatures and exposure times employed in this investigation. The edge distance is defined as the distance from the center line of the 1/4-in. bearing hole to the adjacent edge of the specimen.

The major axis of all test specimens was oriented in the direction of rolling.

Stress-strain characteristics were determined within a 2-in. gage length on the tensile specimens and within a 1-in. gage length on the compression specimens.

In order to facilitate proper loading alignment in the compression tests, special care was taken in machining the compression specimens to insure that the loaded ends were parallel to each other and perpendicular to the longitudinal axis of the specimens.

All of the tensile, compression, and bearing specimens were machined to the final dimensions before they were heat treated and exposed to the aging temperature. The ends of the compression specimens




A. 0.062-in. and 3/16-in.

B. 0.500-in. and 0.375-in.

C. 4-1/8-in. when B = 0.500; 4in. when B = 0.375

Fig. 1. Dimensions of Test Specimens

were ground slightly after heat treatment to insure flatness, smoothness, and proper loading alignment. Since slight distortion or warping of the shear specimens prevented them from fitting easily into the test fixture, they were machined oversize and heat treated before being ground to the final dimensions.

## SECTION IV. TESTING EQUIPMENT

The following are the main items of equipment used in the tests:

1. A 120,000 lb-capacity Baldwin universal testing machine, which was used for loading in all tests.

2. Suitable loading fixtures for the tensile, bearing, compression, and shear tests. These fixtures were designed and made at Southern Research Institute.

3. Preyield and postyield extensometers for the tensile tests, an extensometer for the compression test, and an extensometer for the bearing tests. These fixtures were designed and made at Southern Research Institute.

4. A load-deformation recorder. A standard Baldwin autographic recorder was modified and adapted for this work.

5. A furnace in which the elevated-temperature tests were carried out. This furnace was designed and built at Southern Research Institute.

Most of these items were described in detail in WADC Technical Report 56-340. For the present work, however, several modifications have been made primarily in the compression fixture and in the test furnace. The discussions of the test equipment that follow are intended to review the previous descriptions and to point out the modifications.

### 4.1 Compression Test Fixture

The compression test fixture, as shown in Fig. 2, consisted of a socket, a loading plunger, a subpress, and two guide blocks, all of which were made of quenched and tempered tool steel. The principal modifications were the addition of a socket to facilitate loading alignment and the incorporation of vertical grooves in the faces of the guide blocks to reduce friction.

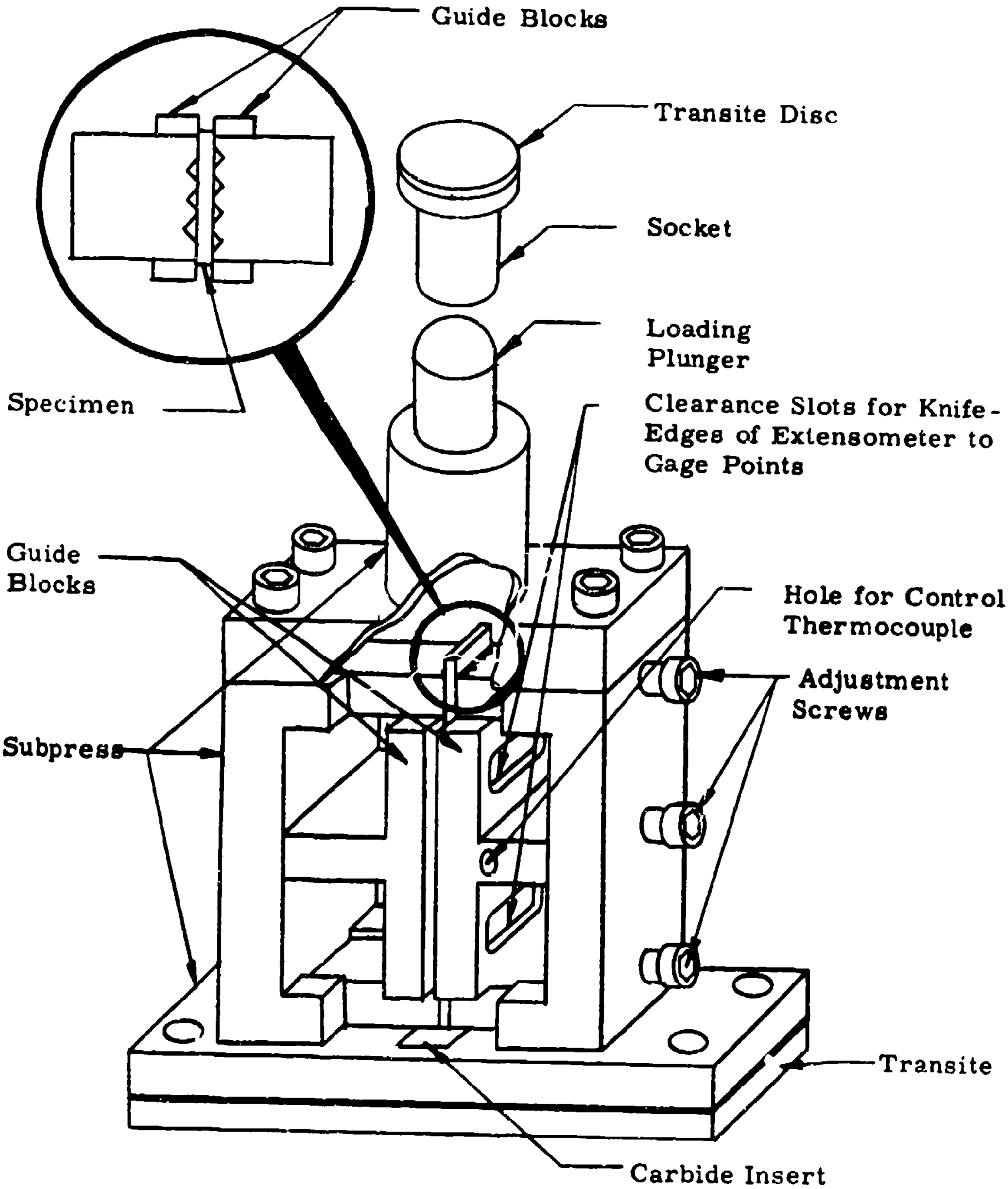



Fig. 2. Compression Test Fixture

To support the concentrated compressive load from the specimen, a carbide insert was incorporated into the base plate of the subpress. The fixture was supported in the furnace, as shown in Fig. 3, on a structural steel pedestal. The pedestal, which extended through the bottom of the furnace, rested on the lower crosshead of the testing machine. A 1/4-in.-thick transite plate separated the fixture from the pedestal. The transite plate contributed to temperature uniformity in the specimens by minimizing heat loss through the pedestal. Also shown in Fig. 3 is the upper end of the compression extensometer.

The guide blocks were necessary to support the specimens and to prevent buckling of the specimens under compressive loading. In order to minimize friction between the guide blocks and the specimens, V-grooves were cut in the bearing surfaces of the guide blocks parallel to the direction of loading. The grooves in the guide block supporting one side of the specimen were offset from the grooves in the other guide block as shown in Fig. 2. Also, to minimize friction the compression specimens were throughly cleaned and lubricated with Molykote. Support pressure on the specimens was controlled by three adjustment screws. To provide a uniform support pressure, the screws were tightened to 5 in. lbs with a torque wrench.

All parts of the subpress were accurately machined to insure, as nearly as possible, perfect vertical alignment of the specimen and the loading plunger. Also facilitating loading alignment was the socket, as shown in Fig. 2, that formed a ball-and-socket joint with the loading plunger. The top of the socket, which was covered with a transite disc to minimize heat losses, was loaded by a heavy rod that extended from the upper crosshead of the testing machine.

### 4.2 Tensile Test Fixture

The tensile specimens were loaded through two pull rods that extended from the upper and lower crossheads of the testing machine and formed clevis linkages with the shoulders of the specimens as shown in Figure 4. Both the clevis pins, which were 1/2-in. in diameter, and the pull rods, which were 1-1/8-in. in diameter, were made of quenched and tempered tool steel.

Figure 4 also shows the extensometer attached to a specimen with the extension rods extending below the specimen and the transducers attached to the lower ends of the extension rods.

### 4.3 Bearing Test Fixture

A photograph of the bearing-test setup including the fixture, extensometer, and a specimen is shown in Fig. 5. Fig. 6 is a schematic

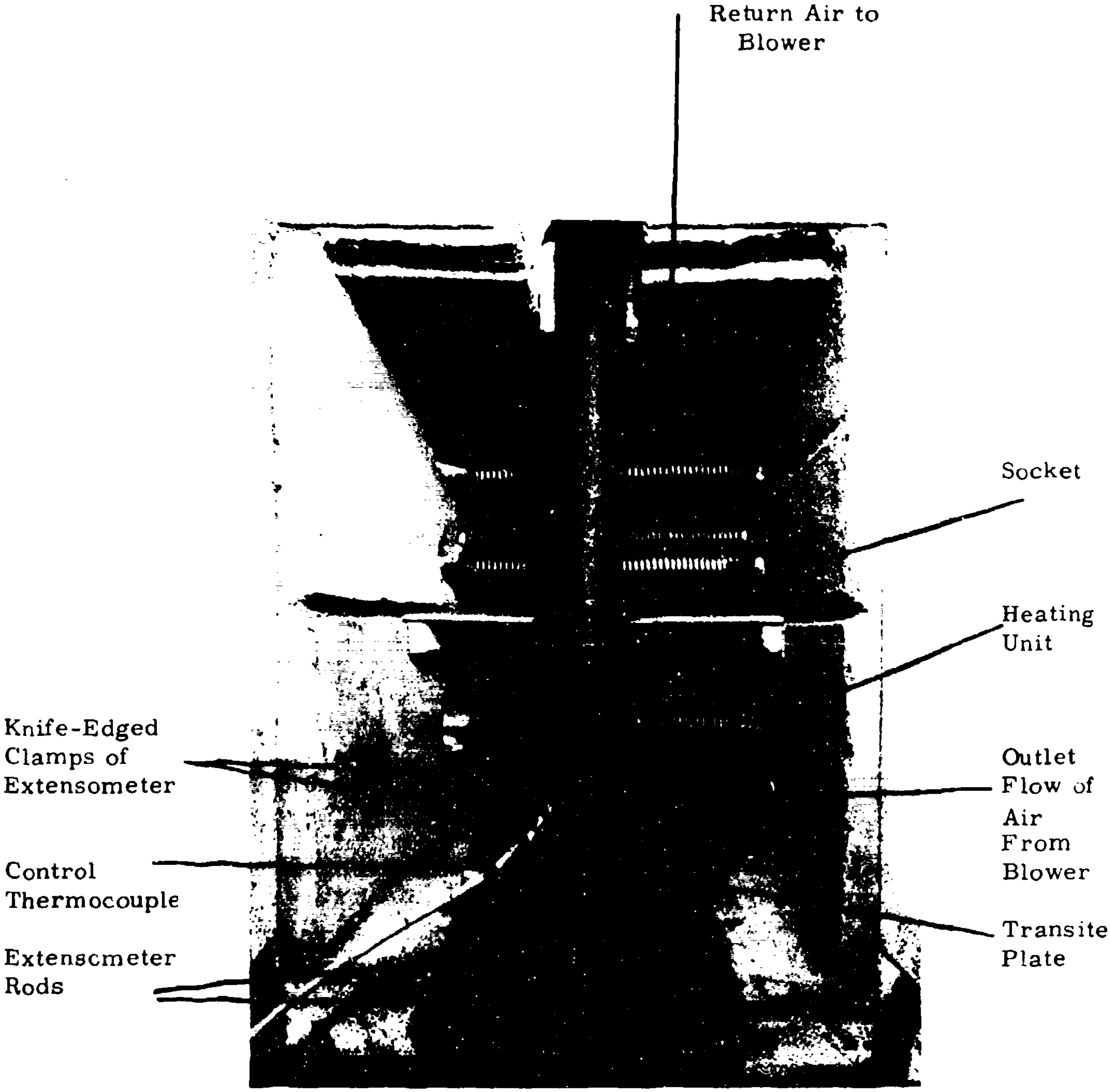



Fig. 3. Compression Test Fixtures in Position in the Test Furnace

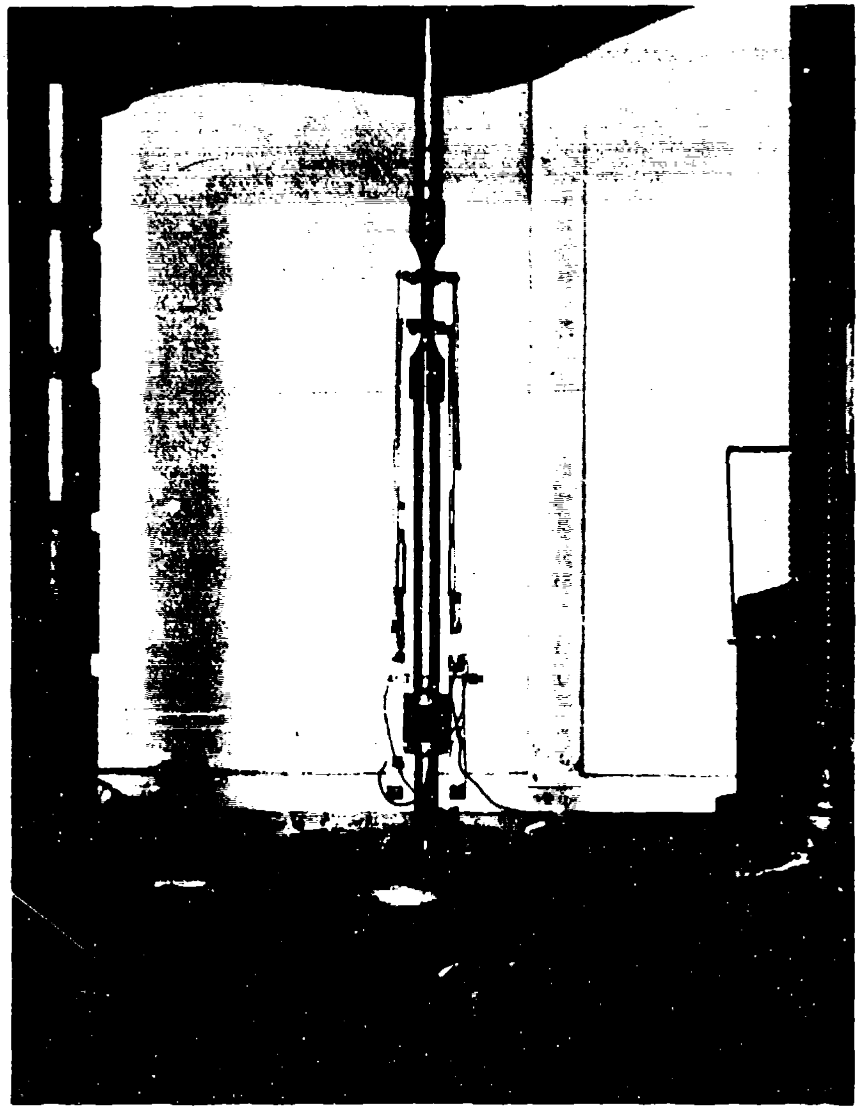


Fig. 4. Tensile Test Apparatus

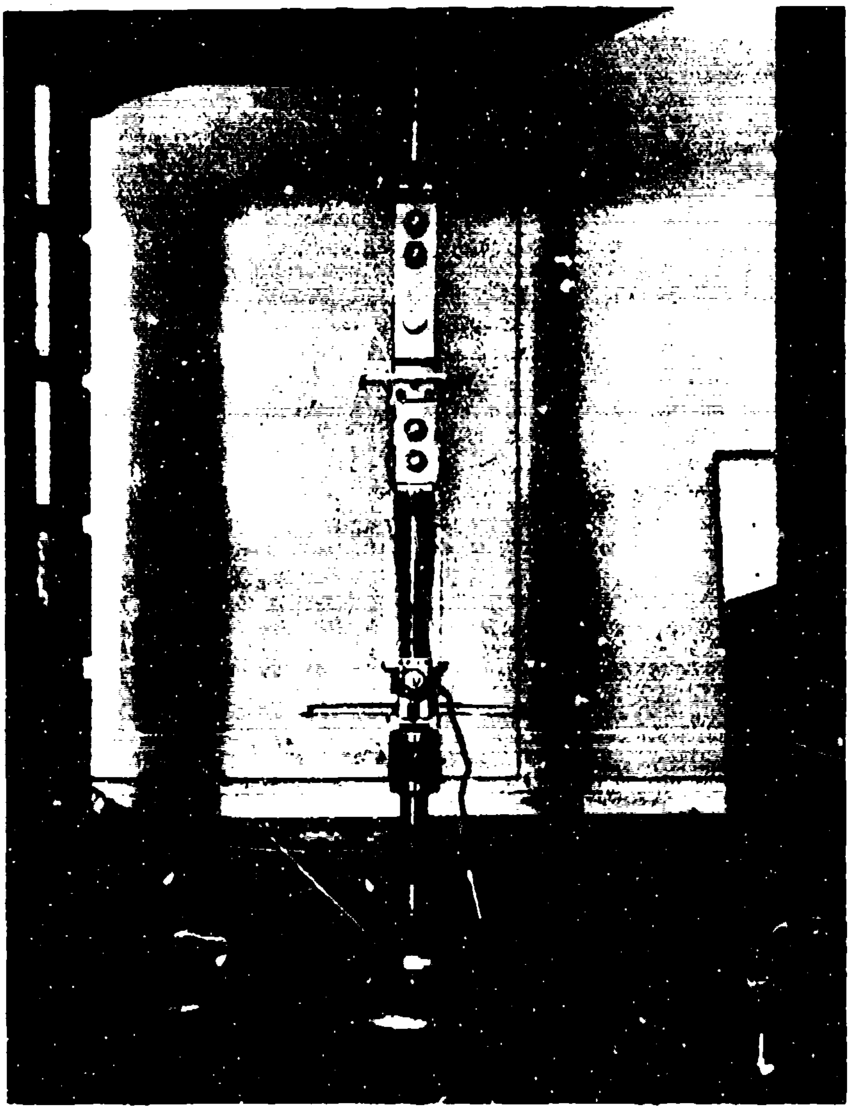


Fig. 5. Bearing Test Apparatus

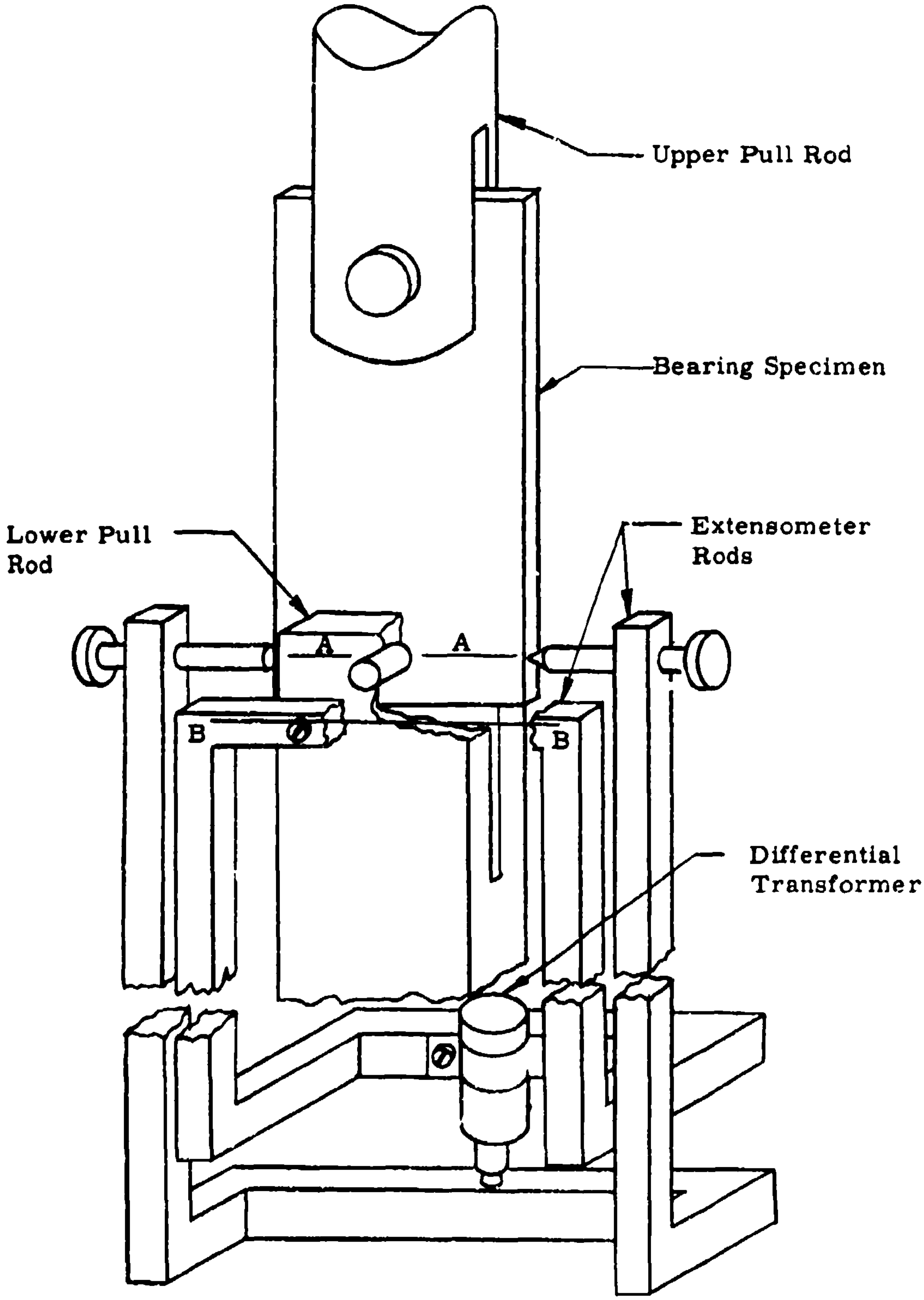



Fig. 6. Diagram of Bearing Test Specimen Assembled to Pull Rods Showing Method of Extensometer Attachment.

illustration of the loading mechanism and of the method of extensometer attachment. The bearing specimens were loaded by two pull rods through clevis linkages at each end of the specimens as shown in Fig. 6. The pull rods and bearing pins were made of hardened and tempered tool steel.

### 4.4 Shear Test Fixture

The shear-test fixture included two pull rods with 1/4-in. slots in one end of each. These pull rods formed clevis linkages with a 1/4-in.-thick center plate as shown in Fig. 7. A 1/2-in. diameter bolt was used for one clevis pin; the shear test specimen was the other clevis pin. The pull rods and center plate were made of quenched and tempered tool steel. Hard, replaceable inserts with 1/8-in. inside diameters were fitted into the bottom clevis holes in the pull rod and in the center plate. These inserts prevented deformation in the fixture in the vicinity of load application to the shear specimens. Both hardened-tool-steel and sintered-carbide inserts were used successfully in this application. The carbide inserts tended to shatter after about five tests or less. Whereas no difficulty was experienced with shattering of the tool-steel inserts, they tended to deform appreciably during tests at temperatures above 1000° F. At test temperatures up to 1000° F, therefore, the tool-steel inserts were used; at higher temperatures carbide inserts were used. Each set of inserts was replaced after twelve or less tests, so that no appreciably deformed inserts were used in any of the tests.

As the shear fixture was loaded in tension, the specimen was held rigid, with little deformation, until it sheared in the two planes that formed the interfaces between the bottom pull rod and the center plate.

### 4.5 Extensometers

Two extensometers were used in the tensile tests. Up to the yield point, a very sensitive and accurate "preyield" extensometer, which was actuated by SR-4 strain-gage transducers, was used. Beyond the yield point, the plastic strain was measured by a less sensitive "postyield" extensometer, which had a differential-transformer transducer. Since two extensometers of different sensitivities were used in the tensile tests, the complete stress-strain curves were recorded in two segments. The first segment, from zero load through the yield point, was recorded on an expanded scale for the accurate determination of modulus of elasticity and yield strength; the second segment, from the yield point to rupture, was recorded on a compressed scale for the determination of ultimate strength, rupture strength, and the general shape of the stress-strain curve.

The preyield extensometer for the tensile tests and the compression extensometer were almost identical in design and in operation. They

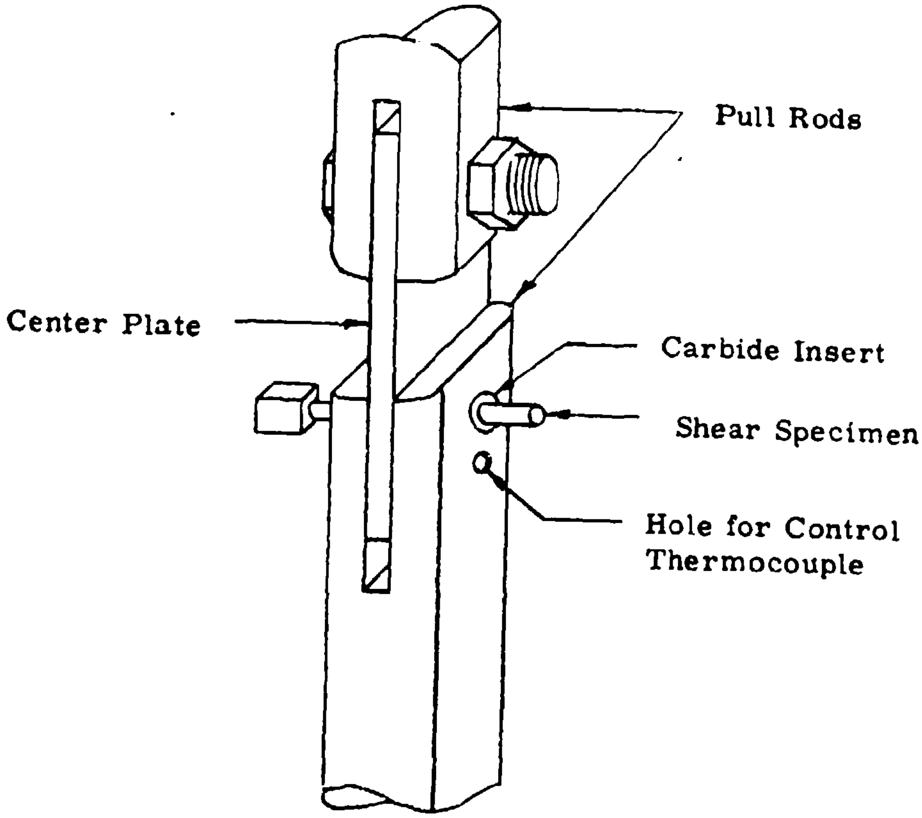



Fig. 7. Shear Test Fixture

consisted of the following parts, all of which are shown on a tensile specimen in Fig. 4.

1. Hardened steel knife edges, which were screw-fastened across the width of the specimens at the gage points.

2. Two sets of stainless steel extension rods, which extended downward from the knife edges out of the test furnace on opposite sides of the specimen.

3. Two SR-4 strain-gage transducers and two steel transducer mounts, which were attached to the lower ends of the extension rods.

The various parts of the transducer mounts and strain-gage transducers are shown in Fig. 8. As the tensile and compression specimens were loaded, the relative displacement between the gage points was transferred through the extension rods and the transducer mounts to the SR-4 strain gages, which were 6 in. long.

A thin beryllium-copper strip was fastened in a horizontal position to the guides of both transducer mounts. This strip prevented any lateral displacement of one mount with respect to the other. The strip, however, was quite flexible in the vertical direction and did not interfere with any differential displacement in the direction of loading. This provision for differential displacement in the direction of loading was necessary to detect and to average the differences in strain on two sides of the specimen.

The active SR-4 strain gages of the tensile and compressive extensometers were connected in a bridge circuit with two dummy gages. Excitation for these extensometers and for all other extensometers used in this work was provided in the form of 15-volt, 60-cycle AC from a transformer in the recorder. The output from the bridge circuit, which was calibrated in terms of strain, was fed into an autographic stress-strain recorder.

When the strain in the tensile tests exceeded the yield point, the circuit of the preyield extensometer was disengaged and that of the postyield extensometer was engaged to feed its calibrated output into the autographic recorder.

A diagram of the tensile postyield extensometer is shown in Fig. 9. The linear-differential-transformer transducer was actuated from the crosshead of the testing machine through a wedge that produced a suitable reduction ratio of crosshead travel to core travel.

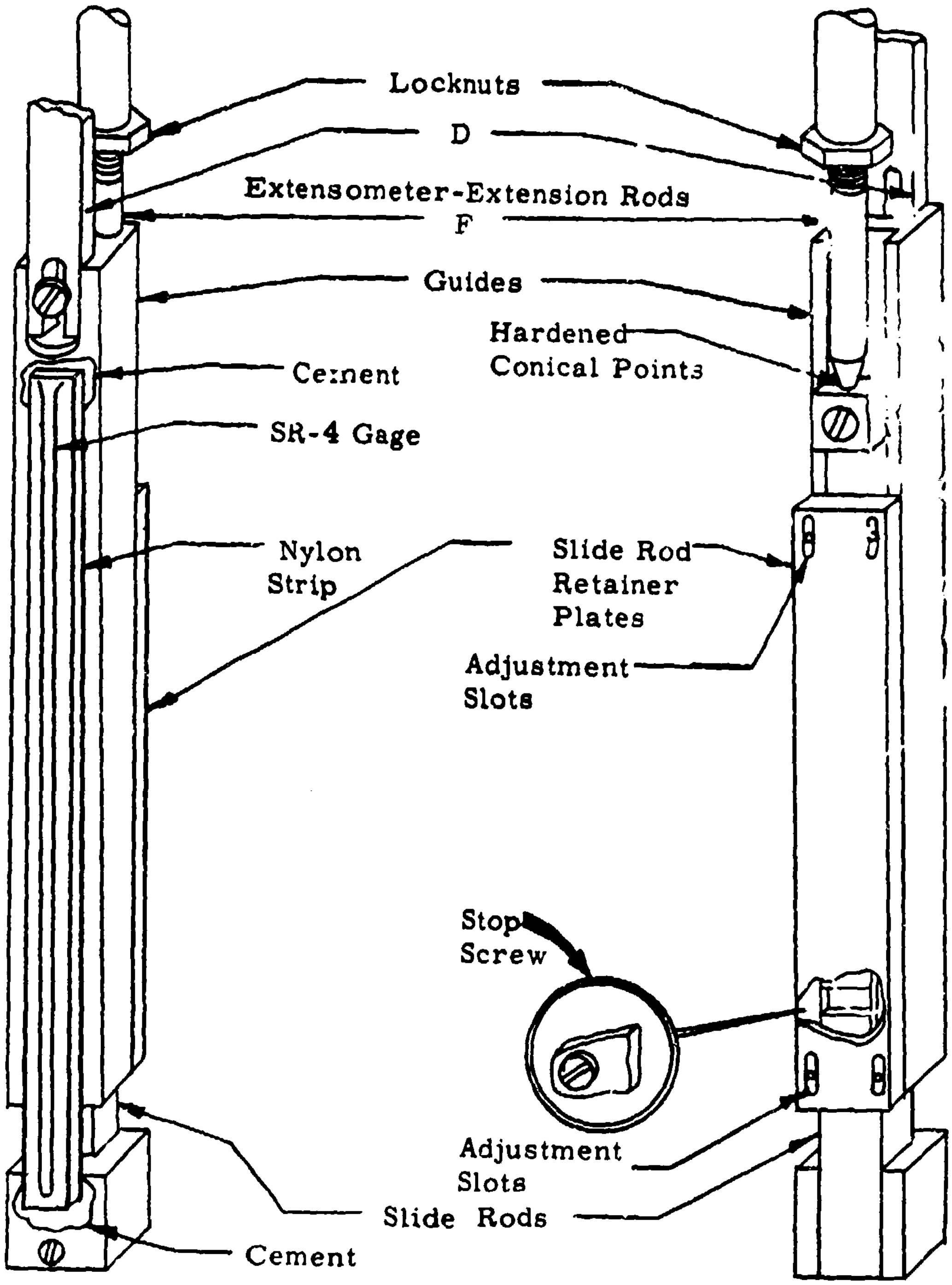



Fig. 8. Strain-Gage Transducers and Transducer Mounts for Tensile and Compression Extensometer

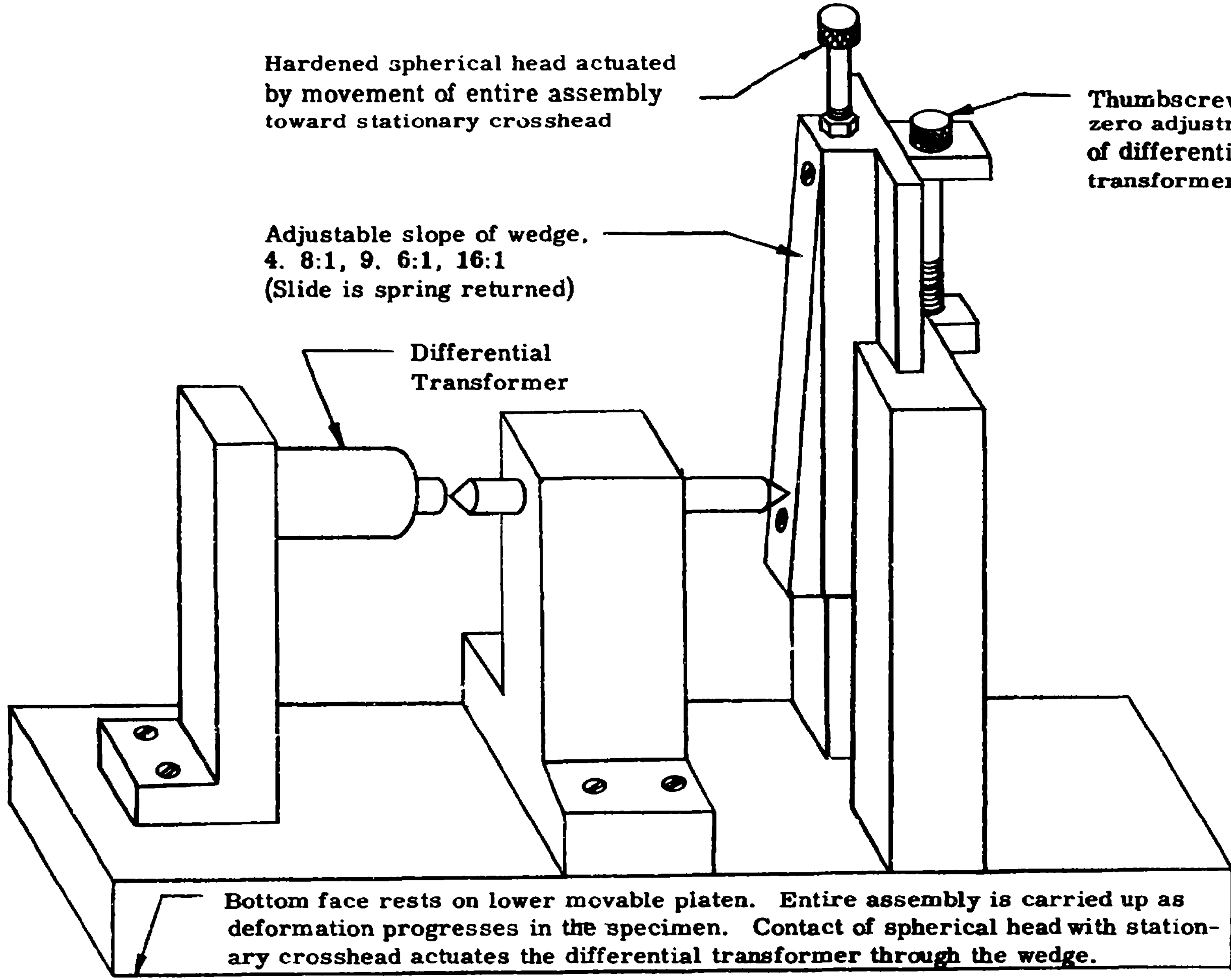



Fig. 9. Postyield Extensometer

The extensometer used in the bearing tests is shown in Fig. 5 and is illustrated schematically in Fig. 6. This extensometer is a modification of one commonly used in elevated-temperature tensile tests. One set of extensometer rods was attached to the edges of the specimen on the horizontal center line of the 1/4-in. bearing hole, which is designated as AA in Fig. 6. The other set of extensometer rods was fastened to the lower pull rod along line BB. Thin brass strips, which can be seen in Fig. 5, were connected between the horizontal sections at the lower end of the extensometer rods. These strips prevented any lateral displacement between the extensometer rods without interfering with vertical displacement.

As the load was applied to the bearing specimen, the extensometer sensed the change in the displacement between lines AA and BB. Since the pull rods and bearing pin had relatively large cross sections in comparison with the specimens, the deformation in these parts was generally negligible. The displacement detected by the extensometer, therefore, was equivalent to the vertical deformation of the 1/4-in. bearing hole.

The calibrated output of the differential transformer of the bearing extensometer was fed into an autographic recorder that recorded the stress-deformation curves.

### 4.6 Stress-Strain Recorder

All of the stress-strain curves obtained in this work were recorded on a Baldwin autographic recorder. The recorder was originally designed and calibrated to operate in conjunction with a Baldwin universal testing machine and with linear-differential-transformer strain transducers. The load channel was mechanically driven from the weighing element of the testing machine. The strain channel was a self-balancing electronic circuit. Provisions were built into this recorder to mechanically vary the load calibration and the strain calibration at several convenient levels on the record charts.

In order to make the recorder self-balancing with strain-gage transducers, it was modified by the addition of a ten-turn potentiometer, which was geared to the balancing motor in the recorder. The potentiometer was wired into one corner of the strain-gage bridge circuit of the extensometer. As the tensile or compression specimens were strained, unbalancing the bridge circuit, the signal caused the balancing motor to drive the recorder in the proper direction to rebalance the bridge by means of the potentiometer. With this circuit, several convenient levels of strain calibration could be achieved on the recorder chart by a change of gears between the balancing motor and the balancing potentiometer.

During the tensile tests, the strain-gage bridge circuit of the preyield extensometer actuated the recorder until the 0.2 %-offset yield strength was exceeded. A manually operated switch, which was added to the recorder, was then used to shift to the differential-transformer circuit of the postyield extensometer. The recorder adjusted itself to the proper strain level on the condensed scale used in conjunction with the postyield extensometer, and then the postyield curve was recorded until the specimen fractured.

### 4.7 Test Furnace

The circulating-air furnace that was described in WADC Technical Report 56-340 was modified considerably for the present work. The modifications were intended primarily to provide for better insulation, longer life of heating elements, better temperature control, and quicker changing of specimens. The furnace is shown in position for the tensile, bearing, and shear tests in Fig. 10.

The Rockwool insulation in the original furnace was replaced with a complete lining of fire brick, which provided better insulation and better resistance to the higher test temperatures. Six edge-wound ribbon-type resistance heating elements with a total capacity of 12 kilowatts were installed to replace the original wire heating coils. The edge-wound elements were much sturdier than the wire coils; and, too, three were installed in the upper air duct and three in the lower air duct of the furnace in such a manner that each could be removed individually for repairs or replacement. These heating elements were wired in series with a saturable reactor, which provided a sensitive and continuous control of heat input.

Slots, extending from the front edges to the opening for the test fixtures, were cut into the top and bottom of the heating chamber. With the furnace door open, these slots allowed the test operator to roll the furnace away from the testing machine between tests without disturbing the test fixture. With the test furnace thus removed from the work area, the operator could change specimens unhampered by heat radiated from the furnace walls. After the furnace was rolled away, the door was closed and the circulating air kept at test temperature while a new specimen was installed. When the furnace was placed back into testing position, the specimen was heated to test temperature within a few minutes. The slots and exposed areas of the openings for the test fixtures were covered with suitably shaped asbestos boards to prevent excessive losses of heat and of air.

Air was circulated in the furnace, by means of a vane-type blower, through the lower duct toward the test chamber, up through the test chamber, and back through the upper duct. This direction of air flow provided better temperature uniformity than the opposite direction did.

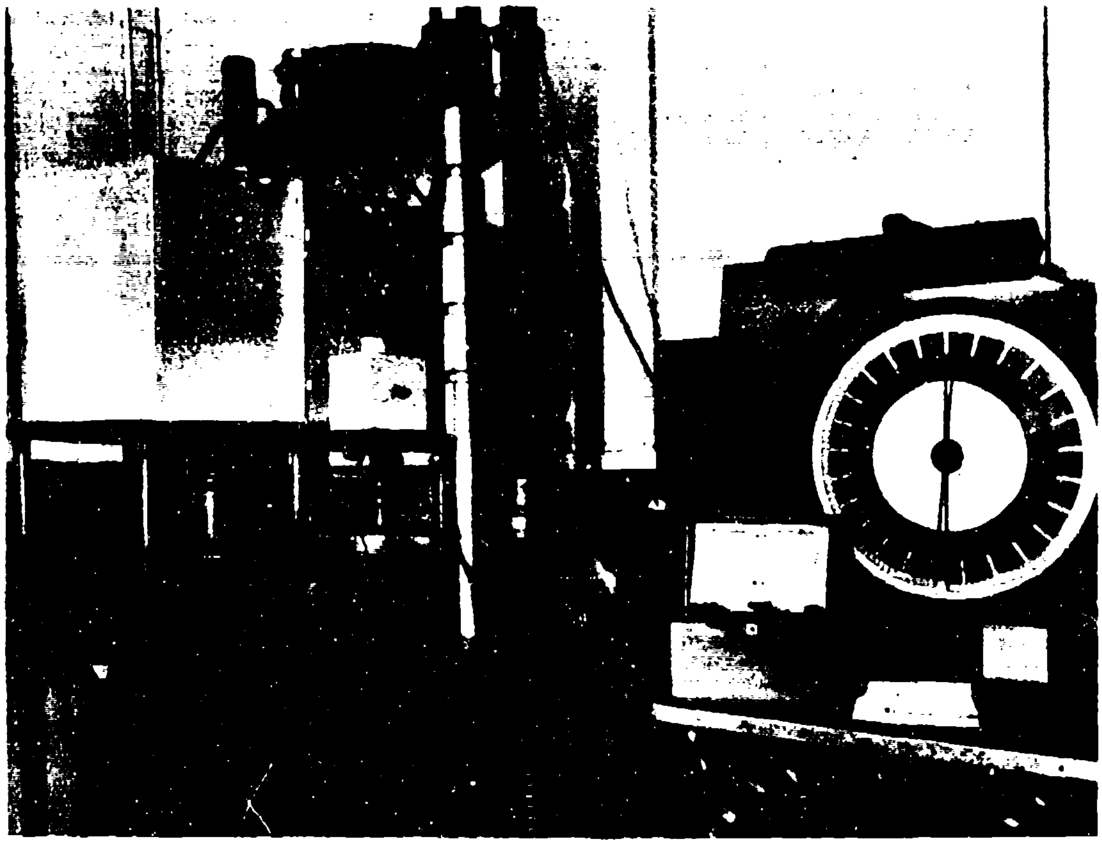


Fig. 10. Test Apparatus Showing Position of the Test Furnace for the Tensile, Bearing, and Shear Tests

## 4.8 Temperature-Control System

The temperature of the test specimen was measured by a thermocouple, which was in contact with the specimen. Responding to the output of the thermocouple, a Foxboro Controller in conjunction with the saturable reactor regulated the current to the heating elements to maintain an almost constant temperature at the specimen. All six of the heating elements and the saturable reactor were connected in series across a 220-volt, 60-cycle power line. Two predetermined power levels were available to the controller for selection by means of a switching action that occurred at the control temperature. Whenever the temperature of the specimen was below the predetermined control temperature, the controller selected the larger power level, which was present to provide a temperature rise. Whenever the temperature of the specimen was higher than the control temperature, the controller selected the lower power level which allowed a slight decline in the test temperature. As the controller cycled between the two power levels the temperature of the specimen was held to a cyclic variation of not more than $\pm$ 5° F.

# SECTION V. CALIBRATIONS AND ACCURACY

## 5.1 Load

The load calibration of the Baldwin testing machine that was used in this work was checked by means of proving rings. The indicated load was consistently accurate within $\pm$ 1% of the actual value throughout the entire range of the machine.

## 5.2 Bearing and Postyield Tensile Extensometer

These extensometers employed Baldwin differential-transformer transducers, the calibrations being furnished by the manufacturer. The ratio of displacement on the strain axis of the recorder chart to core displacement could be controlled to levels of 250, 500, 1000 by proper gearing of the recorder drive mechanism. These calibrations are believed to be accurate to within $\pm$ 3% since this level of accuracy is usually obtainable with linear-differential- transformer transducers.

The error introduced by the detection of postyield strain at the crosshead was determined roughly by comparing measured total elongation with that indicated on the stress-strain curves. In general, the indicated plastic strain was from 5% to 40% higher than the measured strain.

## 5.3 Preyield Tensile and Compressive Extensometer

The accuracy, reproducibility, and linearity of the calibrations of these extensometers were checked by means of the apparatus shown in Fig. 11. This apparatus consisted of a Tuckerman optical strain gage and Autocollimator, the extensometer, a Baldwin SR-4 strain indicator, and a calibrating device, on which the extensometer and the Tuckerman gage could be equally deflected. The calibrating device is shown in Fig. 12.

With this apparatus, the extensometer and the Tuckerman gage were deflected simultaneously in equal increments, and the readings of the Tuckerman gage were plotted against the output of the strain gages as measured by the strain indicator. As discussed in WADC Technical Report 56-340, a statistical analysis of repeated calibrations of this type indicated that in the preyield tensile extensometer the probable error did not exceed 0.5% in 67% of the tests; in the compression extensometer the probable error did not exceed 1.0% in 67% of the tests. Experience in using these extensometers indicates, however, that these levels of accuracy were not consistently achieved, especially in tests at elevated temperatures.

Although reading errors, instrument errors, and errors in the primary standard (Tuckerman gage) probably contributed minor inaccuracies to the calibration and the use of these extensometers, it is believed that the greatest sources of error were mechanical. Mechanical errors can be caused by non-rigidity in certain structural parts of the extensometers and by slippage in the joints or the knife edges. Although this type of error was probably quite small in the calibrations, which were carried out at room temperature, it was probably more severe at elevated temperatures where inconsistencies in modulus values were greater than would be indicated by the accuracy and reproducibility of the calibrations.

In order to calibrate the strain scale of the recorder for use with these extensometers, the apparatus shown in Fig. 11 was used except that the extensometer output was fed into the recorder instead of into the strain analyzer. The calibrating device was actuated to several convenient increments of displacement as indicated by the Tuckerman strain gage; at each increment, the corresponding displacement on the recorder chart was read. Such calibrations, which were run at least once each week on both extensometers, were found to be accurate, reproducible, and linear to the degree indicated by the statistical analysis discussed above.

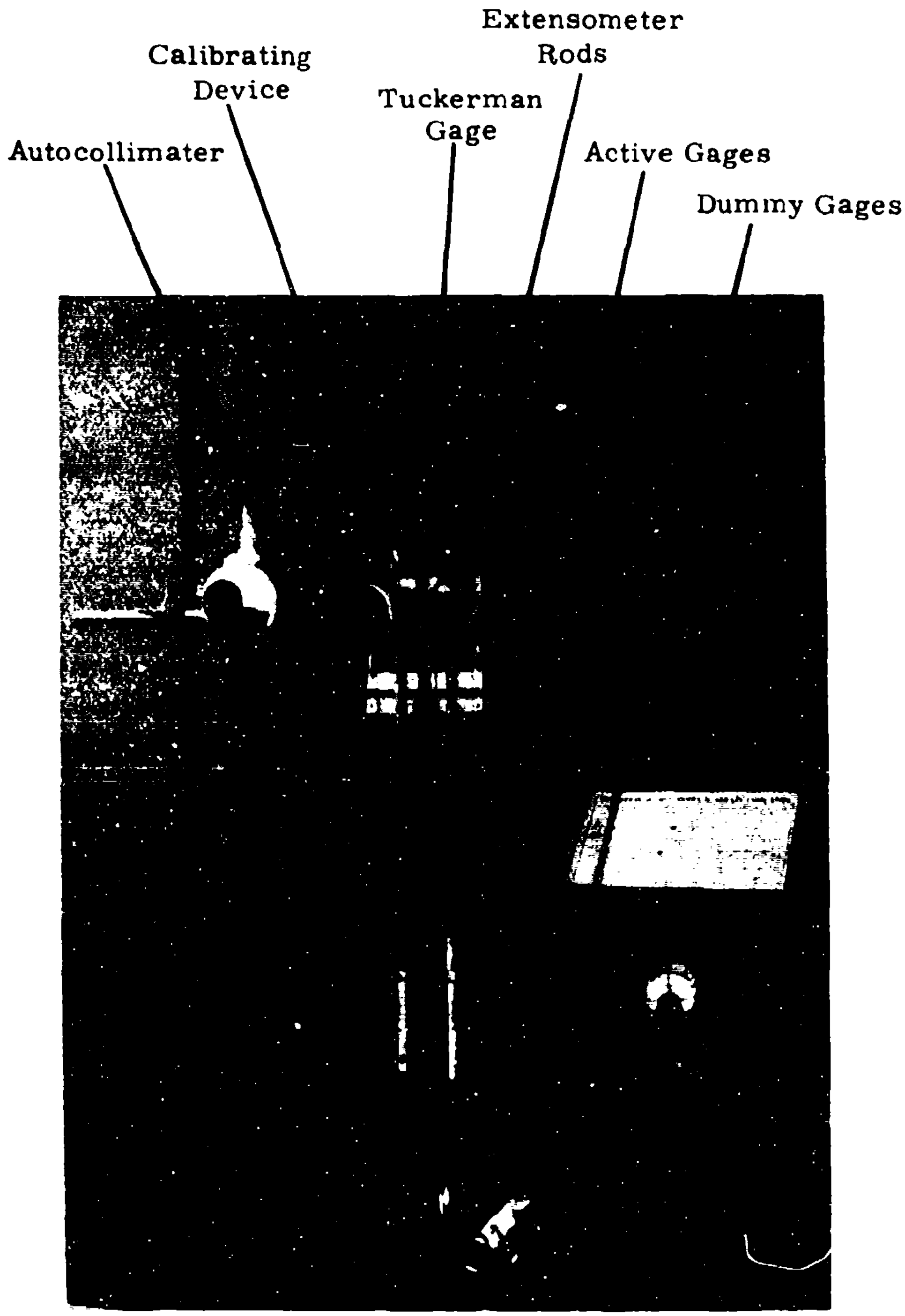



Fig. 11. Setup for Checking Accuracy, Reproducibility, and Linearity of Preyield Tensile and Compressive Extensometer

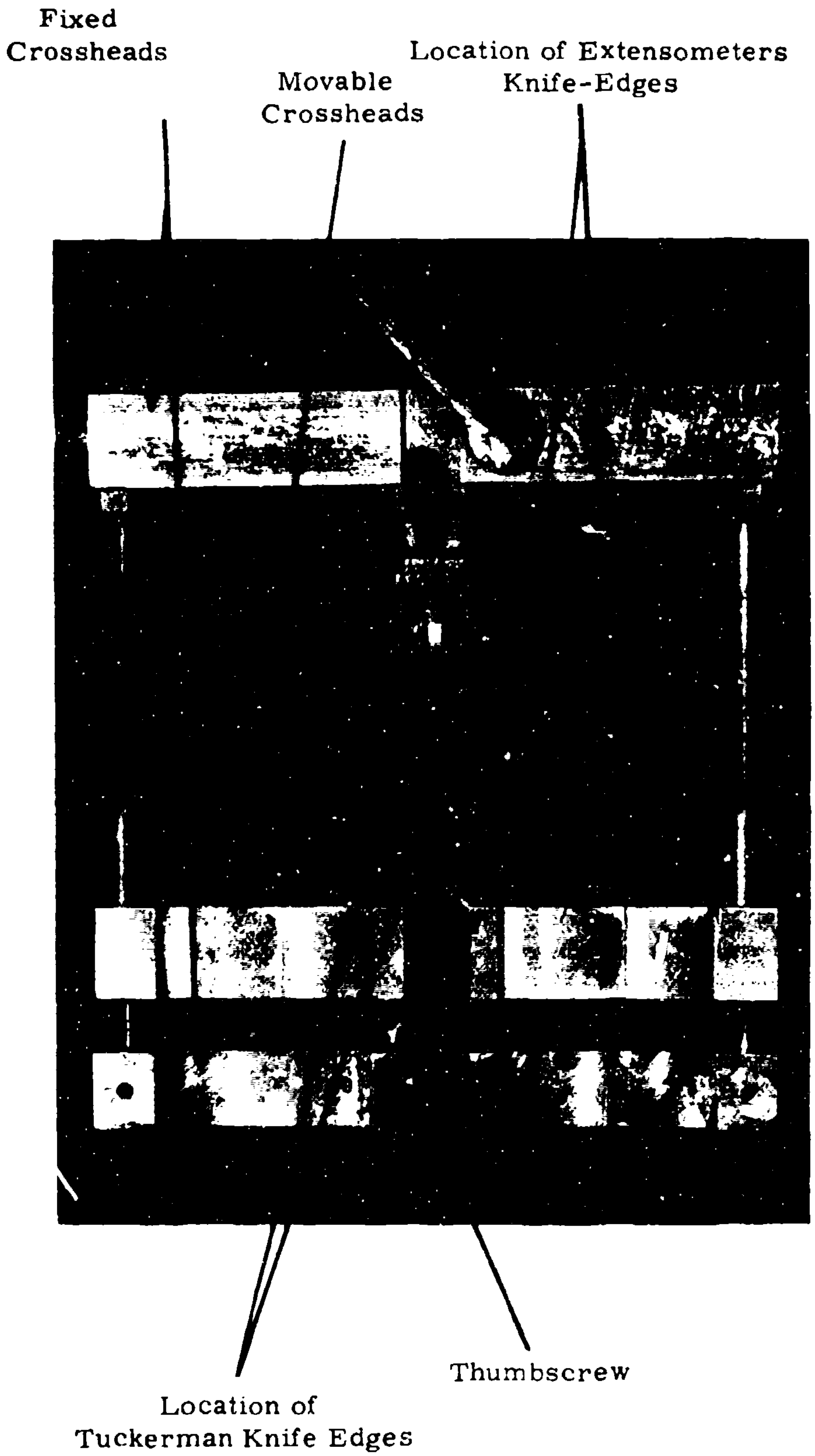



Fig. 12. Calibrating Device

## 5.4 Tensile Elongation

Total elongation of the tensile specimens was measured with a scale graduated in hundredths of an inch. Since this scale could be read to the nearest 0.01 in., the measurements were accurate within ± 0.25% elongation.

## 5.5 Temperature Measurement

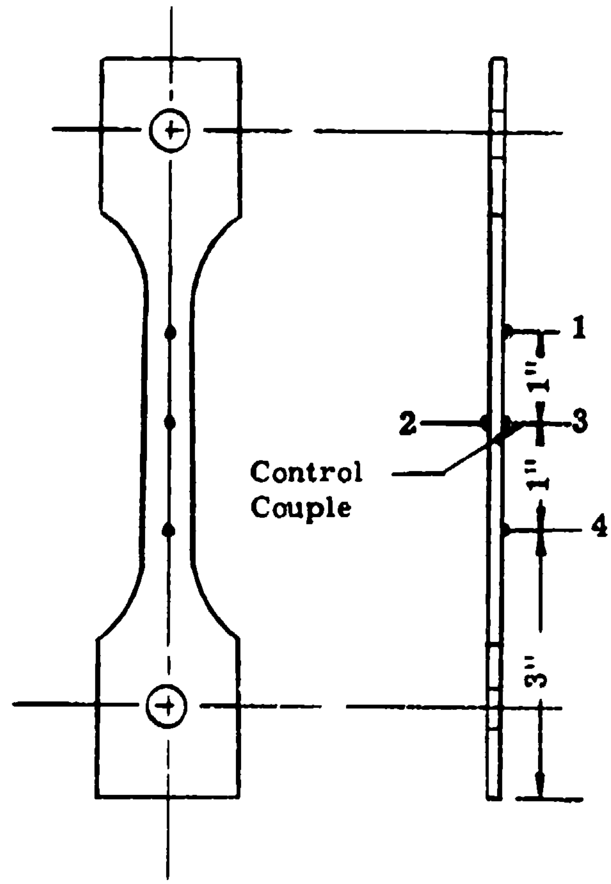
Chromel-alumel thermocouples were used for temperature measurement in this work. These thermocouples are guaranteed by the manufacturer to be accurate within ± 0.75% of the measured temperature in degrees Fahrenheit.

Surveys of temperature distribution were made on specimens of all types while they were in their normal testing positions. In these surveys, four thermocouples, in addition to the normal control couple, were positioned on or near the specimens as designated by the numbers 1, 2, 3, and 4, in Fig. 13, 14, 15, and 16. The tables on these illustrations show equilibrium temperatures at the various thermocouple positions while the control couple was maintained at various test temperatures.

The temperature distributions were reasonably uniform at all test temperatures and with each type of specimen. The greatest nonuniformities, which occurred at the higher test temperatures in the compression and shear specimens, were +8° F and -7° F. The improved temperature uniformities over those reported in WADC Technical Report 56-430 were a result of the following modifications in the test furnace: one, the reversal of the direction of air flow in the heating chamber from downward to upward; second, the inclusion of heating elements in both the top and bottom air ducts, resulting in more uniform radiation of heat to the test fixtures.

# SECTION VI. TEST PROCEDURE

For most conditions of temperature and exposure time, three or more tests of each type were conducted on each test material. At 1100° F and 1200° F, however, the bearing tests on Thermold J alloy steel and on A-286 alloy were not completed since the test fixture tended to deform because of the relatively high strength of the specimens in comparison to that of the fixture at those temperatures.

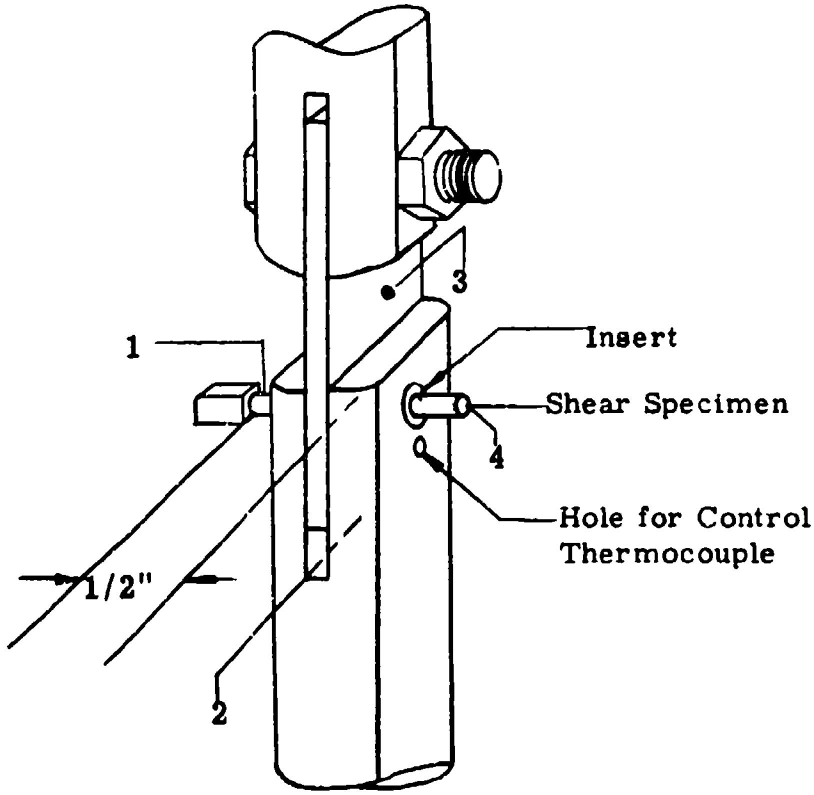



Controller Temperature Setting, ° F

| Temp. at Thermocouples | 400 | 600 | 800 | 1000 | 1200 |
|---|---|---|---|---|---|
| 1 | 398 | 594 | 800 | 1002 | 1202 |
| 2 | 398 | 594 | 802 | 1003 | 1204 |
| 3 | 399 | 594 | 799 | 1002 | 1198 |
| 4 | 400 | 507 | 798 | 1002 | 1198 |

Cyclic-Control Variation ± 5° F

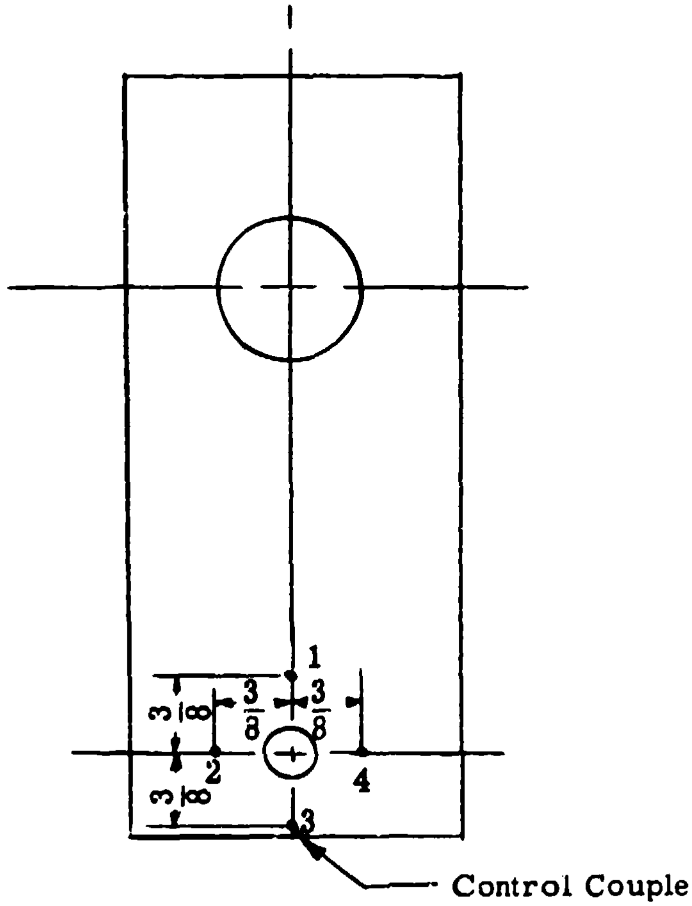
Fig. 13. Tensile Test Specimen Showing Location of Thermocouples and Corresponding Temperature-Distribution Survey.




| Temp. at Thermocouples | Controller Temperature Setting, ° F | | | | |
|---|---|---|---|---|---|
| | 400 | 600 | 800 | 1000 | 1200 |
| 1 | 399 | 596 | 801 | 1003 | 1204 |
| 2 | 399 | 597 | 802 | 1006 | 1208 |
| 3 | 399 | 597 | 802 | 1006 | 1207 |
| 4 | 396 | 597 | 800 | 1002 | 1201 |

Cyclic-Control Variation $\pm 5°$ F

Fig. 14. Shear Specimen Set in Test Fixture Showing Location of Thermocouples and Corresponding Temperatures During Temperature-Distribution Survey.

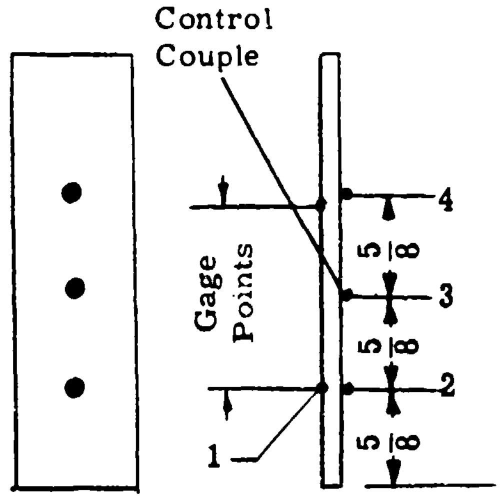



Controller Temperature Setting, ° F

| Temp. at Thermocouples | 400 | 600 | 800 | 1000 | 1200 |
|---|---|---|---|---|---|
| 1 | 402 | 600 | 800 | 997 | 1199 |
| 2 | 402 | 600 | 801 | 998 | 1200 |
| 3 | 401 | 598 | 801 | 1001 | 1205 |
| 4 | 397 | 603 | 801 | 1000 | 1205 |

Cyclic-Control Variation $\pm$ 5° F

Fig. 15. Bearing-Test Specimen Showing Location of Thermocouples and Corresponding Temperatures During Temperature-Distribution Survey




Controller Temperature Setting, °F

| Temp. at Thermocouples | 400 | 600 | 800 | 1000 | 1200 |
|---|---|---|---|---|---|
| 1 | 395 | 598 | 794 | 993 | 1193 |
| 2 | 395 | 598 | 798 | 998 | 1195 |
| 3 | 400 | 603 | 798 | 998 | 1200 |
| 4 | 400 | 602 | 800 | 1000 | 1202 |

Cyclic-Control Variation ± 5° F

Fig. 16. Compression-Test Specimen Showing Location of Thermocouples and Corresponding Temperature During Temperature-Distribution Survey.

Up to the 0.2%-offset yield point, the tensile and compression tests were run at a strain rate of 0.0025 in./in./min. Above the yield point in the tensile tests, the strain rate was increased to 0.020 in./in./min. In the shear and bearing tests, the crosshead speed was set at a rate equivalent to that used in the compression tests.

## SECTION VII. TEST RESULTS

The test results are shown in graphical form in Fig. 17 through Fig. 137, and they are shown in tabulated form in Tables 4 through 39. In the tables, graphs, and discussion below, the results are grouped for the different test materials in the following order:

1. A-286 austenitic alloy

2. 17-7 PH stainless steel

3. The ... old J alloy steel

4. Type 420 stainless steel

5. Type 422 stainless steel

6. 17-22 A (S) alloy steel

Four types of graphs are shown in the following order for each test material:

1. Properties as functions of exposure time at the elevated testing temperatures. The points on these curves represent the average values shown in the tabulated data.

2. Properties as functions of temperature at constant exposure times. In these curves properties are expressed as percentages of room-temperature properties. Average property values were also used in plotting these curves.

3. A typical stress-strain curve for tensile, compression, and bearing ... under each condition. Each of these

curves is a reproduction of the recorded data from one specific test, and does not represent an average. The preyield and postyield tensile stress-strain curves were plotted on separated pages so that a number of curves could be shown on a single page.

4. A typical curve showing tangent modulus as a function of stress for each compression test conditon. Each of these curves also represent results obtained in one specific test rather than average results.

The exposure time for the room temperature tests was considered to be 1000 hours. No data representing shorter holding times at room temperature can be presented since the test metals had been at room temperature for a considerable period of time before being tested.

## 7.1 A-286 Alloy Sheet, Quenched and Tempered

The test results for this alloy are shown graphically in Fig. 17 through 36 and are tabulated in Tables 4 through 9. Fig. 17 shows very little difference in the tensile strengths of the 0.062-in. sheet and 3/16-in. plate throughout the ranges of temperature and of exposure time covered by this work.

In general, variations in exposure time from 1/2 hour to 1000 hours at the various test temperature had no major or consistent effects upon the strength properties and modulus of elasticity of this alloy. Although some small increases in strength and some small decreases in strength occurred after holding times of 100 hours and 1000 hours, particularly at the higher test temperatures, these effects were rather small and inconsistent. Since the A-286 is a precipitation-hardening alloy, it is believed that these fluctuations in strength were a result of precipitation phenomena.

The tensile percent-elongation values of the A-286 alloy were affected very little by variations in temperature and in holding time. After 1/2- hour exposures at temperatures from 600° F to 1200° F, all elongation values were in the range 20% to 27%; after 1000-hour exposures at the same temperatures, the elongation values were in the range 17% to 21%.

Fig. 22, 23, and 24 show that the strength properties and modulus of elasticity of A-286 alloy decreased only a small amount as temperature was increased from 75° F to 1200° F, all of these properties at 1200° F being about 70% or more of the room-temperature properties. At 1200° F, this alloy retained about 90% or more of its room-temperature tensile and compressive yield strengths.

As shown in Fig. 26, 27, and 28, the tensile stress-strain curves of this alloy had a sharp downward discontinuity just before rupture. The shape of the postyield tensile stress-strain curves changed slightly with increasing temperature, the strain at which the ultimate strength was reached decreasing from near the rupture point at 75° F to only slightly beyond the yield point at 1200° F. The compressive stress-strain curves and the bearing stress-deformation curves for this alloy had conventional shapes as shown in Fig. 29 through 33.

Variations in exposure time had no consistent effects upon the compressive tangent modulus curves for this material.

## 7.2 17-7 PH Stainless Steel Sheet, RH 950 Condition

Tables 10 through 15 and Fig. 37 through 56 show the test results for the 17-7 PH stainless steel sheet in the RH 950 condition.

As shown in Fig. 37, under most test conditions the ultimate tensile strength of the 0.062-in. sheet was somewhat higher than that of the 3/16-in. plate. The differences in ultimate tensile strength ranged from about 2000 psi to 22,000 psi.

With the exception of ultimate shear strength, the strength properties of this alloy increased considerably with increasing exposure times at 800° F. At 600° F, the effects of exposure time on the strength properties were, in general, rather small and inconsistent. At 1000° F, some of the strength properties increased, whereas others remained constant or decreased slightly with increasing exposure times. The ultimate shear strength and tensile and compressive moduli of elasticity of this alloy were not significantly affected by variations in exposure time at any of the test temperatures. The tendency for this alloy to increase in strength with increasing exposure at 800° F was probably a result of increased precipitation hardening over that obtained in the heat treatment. The 600° F test temperature was probably not high enough to effect appreciable additional precipitation, whereas the alloy probably tended to overage at 1000° F.

Fig. 39 shows that, whereas the tensile percent elongation of the 17-7 PH (RH 950) was not greatly affected by exposure time, the elongation decreased slightly with increasing temperature up to 600° F and then increased considerably with further increases in temperature up to 1000° F.

The strength properties of this alloy, as shown in Fig. 43 through 46, decreased only moderately with increasing temperatures up to 800° F and then decreased sharply with further increases in temperature, most

strength properties at 1000° F being about 40% of the room-temperature strength. Tensile and compressive modulus-of-elasticity values decreased about 20% to 30% as temperature was increased from 75° F to 1000° F.

At 75° F and 600° F, the stress-strain curves of this material, as shown in Fig. 48, contained a considerable flat portion at the ultimate load, which occurred about midway between the yield point and the rupture point. At 800° F and 1000° F, the ultimate load was reached at a strain only slightly beyond the yield point, and then the load decreased continuously until the specimens ruptured.

The compressive tangent-modulus curves of this material were not appreciably changed by variations in exposure time at 600° F, whereas the increasing stress levels reached in the tangent-modulus curves with the longer exposure times at 800° F and at 1000° F reflect the improved compressive strength with increasing exposure time.

## 7.3 Thermold J Alloy Steel Sheet, Quenched and Tempered

The test data for the Thermold J alloy are tabulated in Tables 16 through 21 and are illustrated in Fig. 57 through 78.

The ultimate tensile strength of the 3/16-in. plate was somewhat higher than the ultimate strength of the 0.062-in. sheet at all test temperatures as shown in Fig. 57. This difference in strength was probably the result of a slight amount of decarburization that occurred during the austenitizing treatment at 1850° F. The decarburized surface layer would be expected to have a greater relative effect on the thinner material. Similar variations between the tensile strengths of the 0.062-in. sheet and the 3/16-in. plate were found, probably for the same reason, in the Type 420 stainless, Type 422 stainless, and 17-22 A (S) alloys.

Increasing exposure times from 0.5 hour to 1000 hour had no significant effect upon the strength properties of Thermold J alloy at temperatures up to 800° F. Over the same range of exposure times at 1000° F and at 1100° F, however, all of the strength properties decreased considerably. Since the test material had been tempered at 1000° F, its structure was, undoubtedly, reasonably stable at lower temperatures. The prolonged exposures at 1000° F and 1100° F, however, had an effect equivalent to additional tempering, which produces coalescence of the carbides and an associated decreased strength.

With the possible exceptions of the large decrease in tensile modulus and moderate decrease in compressive modulus with long exposures at 1100° F, the variations in modulus of elasticity with changes in holding

time are not believed to be significant. The decreases in modulus with increasing exposures at 1100° F are associated with corresponding decreases in tensile and compressive strength, which are a result of structural changes as discussed above. Under these conditions of low strength and structural instability, it is probable that the alloy has poor resistance to creep, i.e. poor resistance to plastic flow below the apparent proportional limit. Modulus-of-elasticity measurements in such materials are quite sensitive to changes in strain rate, modulus apparently decreasing with decreasing strain rate. Such variations in modulus determinations do not represent true changes in elastic properties but, rather, are a result of plastic flow that occurs during the apparent elastic portion of the tests. Since the tensile and compressive tests were run at relatively slow strain rates, it is believed that such plastic flow resulted in the low apparent modulus values in Thermold J after long exposures at 1100° F.

Little variation in tensile elongation occurred in the Thermold J alloy as exposure times were increased from 0.5 hour to 1000 hours at 600° F and 800° F. The tensile elongation increased slightly at 1000° F and increased greatly at 1100° F when exposure times were extended to 1000 hours. These increases were, undoubtedly, associated with the decreases in strength and the structural instabilities discussed above. With increasing temperature, tensile elongation changed very little between 75° F and 600° F and then increased considerably between 600° F and 1100° F.

As shown in Fig. 62 through 65, most of the strength properties of the Thermold J alloy decreased to about 80% of their room-temperature levels as temperature was increased to 800° F and then decreased more sharply with further increases in temperature, the sharper drops in strength occurring in the specimens with the longer exposure times. Tensile and compressive moduli values also decreased with increasing temperatures, but not as sharply as the strength properties.

In the plastic portions of the tensile stress-strain curves, the ultimate load tended to occur at about the same value of strain regardless of the test temperature. As the temperature was increased from 600° F to 1100° F, however, the degree of strain on the descending portion of the curves beyond the ultimate load increased considerably. At 600° F, the descending portion of the stress-strain curves beyond the ultimate load was marked by several abrupt variations in load, the load decreasing sharply and then increasing sharply several times. With each sharp decrease, a "popping" noise was emmitted from the specimen. It is believed that each sharp decrease was a result of a sudden small amount of slippage along certain crystallographic planes. This sudden rapid slippage resulted in a small amount of yielding in the specimen that allowed the

load to decrease. The load then increased again until it was sufficiently high to cause another sudden slippage phenomenon. Once this process started it was repeated until the specimen broke.

At temperatures up to 800° F, the compressive-tangent-modulus curves for Thermold J alloy were not significantly affected by changes in exposure time. As a result of the declining compressive strength with increasing exposure times at 1000° F and 1100° F, the stress levels for the tangent modulus curves decreased with increasing exposure times.

## 7.4 Type 420 Stainless Steel Sheet, Quenched and Tempered

Tables 22 through 27 contain data from tests on Type 422 stainless steel; Fig. 79 through 98 are graphical illustrations of the same data.

In this material, the 3/16-in.-thick plate consistently had slightly higher tensile strength than the 0.062-in.-thick sheet as shown in Fig. 79.

At test temperatures up to 800° F, variations in exposure time had no significant effect upon the strength properties and the tensile elongation of this alloy. Increasing exposure times at 1000° F, however, resulted in appreciable decreases in all strength properties and in increased elongation. Since, in the original heat treatment, the Type 420 had been tempered at 1000° F, the structure was, apparently, stable at lower temperatures. At the 1000° F exposure temperature, however, further tempering—carbide coalescence—resulted in decreased strength and increased elongation. The compressive and tensile moduli of elasticity of this material were not appreciably affected by variations in exposure time and associated structural changes.

The tensile elongation of the Type 420 changed very little with changes in temperature between 75° F and 800° F. When the temperature was increased to 1000° F, the elongation approximately doubled.

The strength properties of this material, in general, decreased less than 20% as the temperature was increased from 75° F to 800° F. As the temperature was increased from 800° F to 1000° F, the strength properties dropped sharply to levels between 60% and 30% or less of the same properties at room temperature. Tensile and compressive moduli of elasticity decrease less rapidly with increasing temperature, the values at 1000° F being 70% or more of those at room temperature.

In the tensile stress-strain curves at temperatures up to 800° F, the ultimate tensile strength was reached after about one half or more of

the plastic strain had occurred as shown in Fig. 89 and 90. At 1000° F, however, the ultimate strength was reached just beyond the yield point. As in the Thermold J alloy at 600° F, Fig. 89 shows that the plastic strain in the Type 420 stainless at 600° F occurred in a very discontinuous manner after the ultimate load was reached. Each sharp decrease in load was again accompanied by a "popping" noise, which is believed to be associated with sudden small amounts of slippage on certain crystallographic planes.

The compressive tangent-modulus curves for this material were affected very little by changes in exposure time at temperatures up to 800° F. At 1000° F, the stress levels for the tangent-modulus curves decreased with increasing exposure times because of the decreasing compressive strength.

## 7.5 Type 422 Stainless Steel Sheet, Quenched and Tempered

The test data for this material are tabulated in Tables 28 through 33 and are illustrated in Fig. 99 through 117. In the various tables and graphs for this material, it will be noted that, with the exception of ultimate tensile strength, the data for the 10-hour exposure time at 400° F are not shown. Whereas all tests representing this condition were run, the strength values were unusually low because, it is believed, the specimens were inadvertently aged at 1200° F instead of at 400° F. Additional tensile specimens, both from the 0.062-in. sheet and from the 3/16-in. plate, were prepared and tested after 10-hour exposure at 400° F. As shown in Fig. 99, the ultimate tensile strengths determined in these check tests were in close agreement with the results for the other exposure times. Although sufficient time was not available for a complete set of check tests, it is felt that the checks on the ultimate strength prove that the original data were erroneous, and that no unusual effects on the strength of this alloy are produced by a 10-hour exposure at 400° F.

Fig. 99 shows that the strength of the 3/16-in. plate was somewhat higher than that of the 0.062-in. sheet at all test temperatures.

Variations in exposure time had no effect upon the strength properties of this alloy at temperatures up to 800° F. The strength properties tended to decrease only slightly with increasing exposure times at 1000° F, which is equivalent to the tempering temperature used in the heat treatment of this alloy. This decrease in strength was, undoubtedly, a result of the continuation of the tempering process during the exposures at 1000° F. No significant changes in tensile and compressive modulus of elasticity occurred as a result of variations in exposure time at any of the test temperatures.

As shown in Fig. 101, only minor variations in tensile elongation occurred in Type 422 stainless steel as a result of variations in exposure time. The percent elongation, which was practically constant at temperatures between 75° F and 800° F, increased appreciably when the temperature was increased from 800° F to 1000° F.

Both the strength properties and the moduli of elasticity of the Type 422 stainless decreased at a rather moderate and uniform rate with increasing temperatures from 75° F to 1000° F. At 1000° F, most of these properties were approximately 60% or more of the same properties at room temperature.

Fig. 108 and 109 show that very little change occurred in the shape of the tensile stress-strain curves as the temperature varied between 75° F and 800° F, rupture occuring at only a small degree of strain beyond the ultimate load. At 1000° F, the ultimate load occurred at a smaller amount of strain, and the specimens elongated a great deal more beyond the ultimate load.

The compressive tangent-modulus curves, as shown in Fig. 115, 116, and 117, varied only slightly with changes in exposure time, the largest variations occuring at 1000° F as a result of the decrease in strength with increasing exposure time.

## 7.6 17-22 A (S) Alloy Steel Sheet, Quenched and Tempered

The test results for this alloy, which are given in Tables 34 through 39, are plotted in Fig. 118 through 137. Fig. 118 shows that the 3/16-in. plate had somewhat higher tensile strength than the 0.062-in. sheet at all test temperatures.

Variations in exposure time, in general, had only minor and rather inconsistent effects upon all of the properties of this alloy. At 1000° F, some of the strength properties tended to decrease slightly with increasing exposure times, whereas the other strength properties remained practically constant; at lower temperatures, some of the strength properties tended to increase slightly with increasing exposure times, whereas the other strength properties remained practically constant.

Variations in temperature and in exposure time had very little effect upon the tensile elongation of this alloy, all of the values that were determined falling in the range 11% to 18% as shown in Fig. 120.

The ultimate-strength and rupture-strength properties of the 17-22 A (S) alloy remained almost constant as the temperature was increased from 75° F to 600° F, whereas most of the yield-strength properties decreased somewhat in this temperature range. This behavior of the strength properties of 17-22 A (S) alloy at temperatures between 75° F and 600° F is typical of low-alloy steels and of carbon steels. It is a result of strain aging, which is believed to be associated with a migration of carbon atoms to dislocation sites in the lattice structure when the metal is plastically strained. At temperatures up to about 700° F the carbon atoms tend to "pin" the dislocations, which phenomenon has a strengthening effect. Since plastic strain is necessary for strain aging, the strengthening effect is usually greater on ultimate strength and on rupture strength than on yield strength. At 1000° F, all of the strength properties of the 17-22 A (S) alloy, with the exception of the tensile rupture strength were in the range 60% to 80% of the room-temperature values. The tensile rupture strength at 1000° F, however, had decreased to 20% to 40% of the room-temperature rupture strength. As the temperature was increased from 75° F to 1000° F, the tensile and compressive moduli of elasticity of this alloy decreased continuously to values equivalent to about 60% to 80% of the room-temperature values.

At temperatures up to 600° F, all of the stress-strain curves for this material were quite similar in shape, the stress falling off rapidly to the rupture point immediately after the ultimate load had been reached as shown in Fig. 128. Fig. 129 shows that, at 800° F, the ultimate load occurred at a relatively lower degree of strain approximately midway between the yield point and the rupture point. At 1000° F, the ultimate load was reached just beyond the yield point, and then the load decreased gradually until the rupture point was approached.

Variations in exposure time had no consistent effects upon the compressive tangent-modulus curves for this alloy as shown in Fig. 135 through 137.

## SECTION VIII. DISCUSSION

Fig. 138 and 139 show comparisons of the strengths of the test alloys after exposures of 1000 hours and of 1/2 hour at the various test temperatures, Fig. 138 representing ultimate tensile strengths and Fig. 139 representing compressive yield strengths.

As shown in these illustrations, at temperatures up to 800° F, the higher strengths were exhibited by the Thermold J, 17-7 PH (RH 950), and Type 420 alloys, whereas progressively lower strengths were found in the Type 422, A-286, and 17-22 A (S) alloys. These strength levels, however, do not necessarily provide valid comparisons of the optimum strengths obtainable in all of the test alloys. The Type 422 stainless, for example, was tempered at 1000° F whereas the Type 420 was tempered at 900° F. The lower tempering temperature accounts for the higher strength in the Type 420. A more valid comparison would have been obtained if these two stainless alloys had been tempered at equal temperatures. The two alloy steels—Thermold J and 17-22 A (S)—were tempered to widely different hardness levels, Thermold J being tempered at 1000° F and the 17-22 A (S) at 1300° F, which is a relatively high tempering temperature for a low-alloy steel of this type. Tempering treatments to equivalent hardness levels would have provided a sounder basis for comparison of the properties of these two alloys.

As the temperature was increased above 800° F, the strength of the Thermold J, 17-7 PH (RH 950), and Type 420 decreased sharply, whereas the strength of the Type 422 and 17-22 A (S) decreased only moderately. The A-286 decreased in ultimate tensile strength only slightly and in compressive strength negligibly as the temperature was increased from 75° F to 1200° F. At temperatures above 1000° F after the exposure time of 1000 hours, the strength of the A-286 exceeded those of all other test metals. After the one-half-hour exposure at temperatures of 1000° F and above, only the strength of the Thermold J exceeded that of the A-286. The strength of the Type 422 stainless, which was relatively low at low temperatures, equaled or exceeded those of the Type 420 and 17-7 PH (RH 950) alloys at 1000° F.

Fig. 138 and 139 show plainly the decreases in strength in the Thermold J, Type 420 and Type 422 with increasing exposure times at 1000° F as discussed previously. They also show the large increase in strength in the 17-7 PH (RH 950) with increasing exposure time at 800° F and the fluctuations in strength in the A-286, as a result of precipitation phenomena, at temperatures between 800° F and 1200° F.

In order to show any simple correlations among the different properties, the following ratio relationships were determined for each test material at each test temperature:

1. Ultimate bearing strength, e/d = 2, to ultimate shear strength.

2. Ultimate bearing strength, e/d = 2, to ultimate tensile strength.

3. Ultimate bearing strength, e/d = 2, to ultimate bearing strength, e/d = 1.5.

4. Tensile modulus of elasticity to compressive modulus of elasticity.

5. Tensile rupture strength (based on original cross-sectional area) to ultimate tensile strength.

6. Tensile rupture strength (based on final cross-sectional area) to ultimate tensile strength.

7. Ultimate shear strength to ultimate tensile strength.

8. Bearing yield strength, e/d = 2, to tensile yield strength.

9. Bearing yield strength, e/d = 2, to bearing yield strength, e/d = 1.5.

10. Compressive yield strength to tensile yield strength.

In order to detect any important effects of exposure time on these ratios, they were calculated both for the tests carried out after the one-half-hour exposure time and for tests carried out after the one-thousand-hour exposure time at each test temperature. Only property values determined under the same conditions of temperature and of exposure time were used in calculating the individual values of the ratio relationships.

The ratio relationships are shown as functions of temperature in Fig. 140 through 151. For legibility, the plots of the various relationships are shown on two graphs for each test material.

In all of the test metals, some fluctuations occurred in the ratio relationships as a result of variations in temperature and in exposure time. In most instances, these fluctuations were minor and inconsistent and are not believed to be significant. None of the ratio relationships in the A-286 alloy, for example, changed greatly with increasing temperature or with increasing exposure time. In general, the ratios of ultimate bearing strength (e/d = 2) to ultimate shear strength tended to decrease appreciably with increasing temperatures, whereas the ratios of ultimate shear strength to ultimate tensile strength increased over the same temperature range. These effects, which were only minor in A-286 alloy and in 17-22 A (S) alloy, were quite pronounced in the other test alloys. The ratios of tensile rupture strength (based on both the original and on the final cross-sectional areas of

the specimens) to ultimate tensile strength tended to decrease with increasing temperatures, although these effects were not entirely consistent in the A-286, 17-7 PH (RH 950), and Type 422 alloys.

In most of the test alloys, the change in exposure time from 1/2 hour to 1000 hours resulted in deviations in some of the ratio relationships primarily at the higher test temperatures. These deviations, which were most pronounced in the 17-7 PH (RH 950 ), Thermold J, Type 420 alloys, were, in general, quite inconsistent and are not believed to be highly significant.

Table 40, which shows the ratio relationships for all of the test metals at room temperature, provides an indication of the consistency of the ratios among different alloys at a single temperature and a single exposure time, the exposure time for the room-temperature tests being considered infinite. The ratios shown in Table 40 are reasonably consistent among the different test materials; $\pm$ 20% about the middle of the range is the greatest percentage variation, occuring in the ratio of tensile rupture strength (based on the final cross-sectional area of the specimen) to ultimate tensile strength. For a number of the ratio relationships at room temperature——ultimate bearing strength (e/d = 2) to ultimate tensile strength, ultimate bearing strength (e/d = 2) to ultimate bearing strength (e/d = 1.5), and tensile modulus to compressive modulus——the variations about the middle of the range were less than $\pm$ 5%.

For each test metal, Table 41 shows the maximum and minimum ratio relationships based upon the test results for the 1/2-hour and 1000-hour exposure times over the entire range of test temperatures. The over-all ranges of ratio relationships for the combined test metals are also shown in this Table. These over-all relationships varied about their mean values by the following percentages:

1. Ult. bearing str., e/d = 2, to ult. bearing str. e/d = 1.5, $\pm$ 17%.
2. Ult. bearing str., e/d = 2, to ult. tensile str., $\pm$ 18%.
3. Compressive yield str. to tensile yield str., $\pm$ 18%.
4. Bearing yield str., e/d = 2, to tensile yield str., $\pm$ 23%.
5. Bearing yield str., e/d = 2, to bearing yield str., e/d = 1.5, $\pm$ 25%.
6. Tensile mod. of elast. to compressive mod. of elast., $\pm$ 30%.

7. Ult. shear str. to ult. tensile str., ± 30%.

8. Ult. bearing str., e/d = 2, to ult, shear str., ± 33%.

9. Tensile rup. str. (based on final cross-sectional area) to ultimate tensile strength ± 54%.

10. Tensile rup. str. (based on original cross-sectional area) to ultimate tensile strength ± 71%.

The general magnitudes of the various ratio relationships were quite similar to those determined for other alloys in previous work as reported in WADC Technical Report 56-340. The variations of the relationships about their means were also of the same order of magnitude, although somewhat less consistency would be expected in the present values since they were based upon data for 1/2-hour and 1000-hour exposure times rather than upon data that represented 1/2-hour exposure times and the averages for all exposure times as in the previous work.

As in the previous work, the numerical values of some of the ratio relationships can be explained on the basis of the configuration of the specimen and the method of load application. In the bearing specimens, for example, which usually failed in shear, the ratio of sheared area in specimens with e/d = 2 to sheared area in specimens with e/d = 1.5 was 1.33. This ratio is roughly equivalent to the ratio relationships of the ultimate bearing strengths of the two types of bearing specimens. In general, the ratios of bearing yield strength for the two types of specimens were slightly lower. These facts show that the ultimate-bearing-strength values varied in proportion to the sheared fracture area, which increased in proportion to the edge-distance to hole-diameter ratio. Since the bearing-yield strength values did not consistently increase to a similar degree with increasing shear area, it is believed that bearing yield strength is governed more by the characteristics of the metal immediately adjacent to the bearing hole than by the entire area that subsequently fails in shear.

Since both the bearing specimens and the shear specimens failed in shear, the ratio of the fracture areas correlated roughly with the ratio relationships of ultimate bearing strength to ultimate shear strength. The ratio of the fracture area in bearing specimens with e/d = 2 to the fracture area in the shear specimens was 2.83, which is near the middle of the range of the ratio of ultimate bearing strength to ultimate shear strength for all test metals.

The greatest scatter in the ratio relationships occurred in the 17-7 PH (RH 950) alloy. As shown in Table 41, of the ten types of ratio relationships

reported, both the maximum and minimum values for four of the relationships in the combined test results were determined by the maximum and minimum values for the 17-7 PH (RH 950) alloy. In two other relationships, either the combined maximum value or the combined minimum value was determined by the 17-7 PH (RH 950) alloy. The reason for the unusually large scatter in the ratio relationships of this alloy is not known.

## SECTION IX. CONCLUSIONS

The strength properties of the six test alloys, in general, decreased only slightly with increasing temperature from 75° F to 800° F. With further increases in temperature, the alloys with higher room-temperature strength—Thermold J, 17-7 (RH 950), and Type 420—weakened decidedly. Of the materials with lower room-temperature strength, the Type 422 and 17-22 A (S) weakened only moderately at temperatures up to 1000° F and the A-286 weakened only slightly at temperatures up to 1200° F. The moduli of elasticity of the various alloys decreased moderately, but consistently, with increasing temperatures. Tensile elongation values reacted erratically with changes in temperature, the higher elongations usually occurring at the highest test temperatures.

As a result of tempering reactions, the strength of the Thermold J and Type 420 decreased considerably and the strength of the 17-22 A (S) and Type 422 decreased slightly with increasing exposure times from 1/2-hour to 1000 hours at temperatures of 1000° F and above. At lower temperatures, since the structures apparently were stable, the properties of these alloys were not significantly affected by variations in exposure time. With increasing exposure times, precipitation phenomena resulted in an appreciable increase in the strength of 17-7 PH (RH 950) stainless at 800° F and in irregular fluctuations in the strength properties of the A 286 alloy at temperatures between 800° F and 1200° F. At other test temperatures, the 17-7 PH (RH 950) and the A-286 alloys were not appreciably affected by changes in exposure time. Moduli-of-elasticity values were not significantly affected and tensile-elongation values were affected only moderately or not at all by variations in exposure time, elongation values usually increasing when strength decreased as a result of prolonged exposures.

A comparison and correlation of the various properties showed that their ratio relationships for equivalent test conditions varied somewhat with differences in the material, in the temperature, and in the exposure time. For

this reason, it is not possible to calculate highly accurate design data for a given property by means of a general factor relating that property to another property that has been determined experimentally. Precise and reliable data on the tensile, compressive, bearing, and shear properties of aircraft-structural materials can presently be obtained only by testing under the desired conditions.

Nevertheless, if the relationships that were determined in this work are used with a full understanding of their inaccuracies and their limitations, they will provide a fair indication of certain properties by calculation from a different property determination. The accuracy and consistency of the ratio relationships between different properties improves as the range of conditions from which they are obtained and to which they are applied becomes more restricted. For example, for the tests at room temperature, three of the ten relationships that were determined varied by less than $\pm$ 5%, whereas only one varied as much as $\pm$20% among the six test alloys. When tests for the entire ranges of temperature and exposure time for all test materials are considered, the accuracy and reproducibility among the ten ratio relationships varied from $\pm$ 17% to $\pm$ 71%.

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## SECTION X. FIGURES AND TABLES OF TEST RESULTS

### 10.1 A-286 Alloy Sheet, Quenched and Tempered

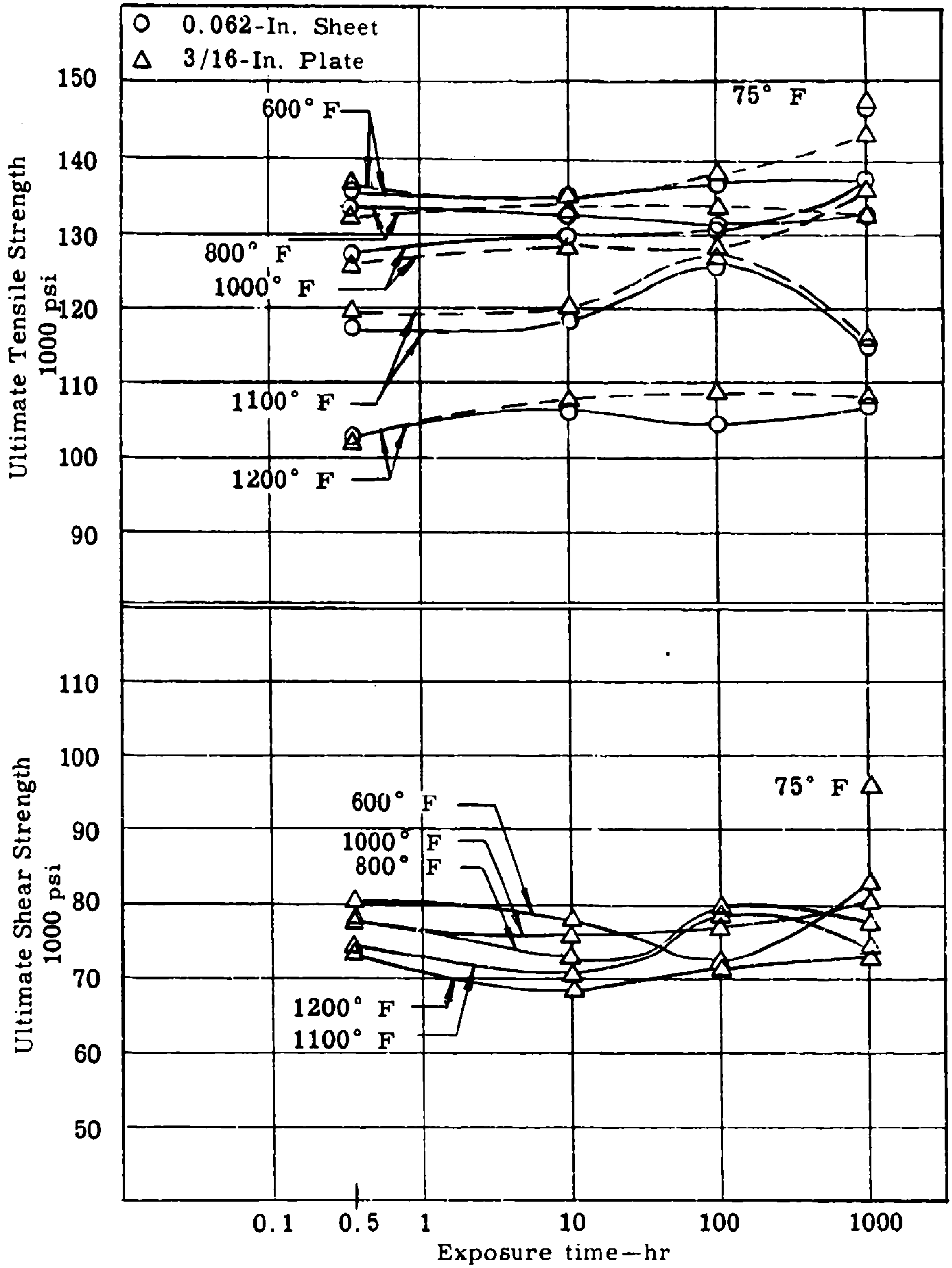


Fig. 17. Effect of exposure time on the ultimate tensile strength and ultimate shear strength of quenched and tempered A-286 austenitic alloy at different temperatures.

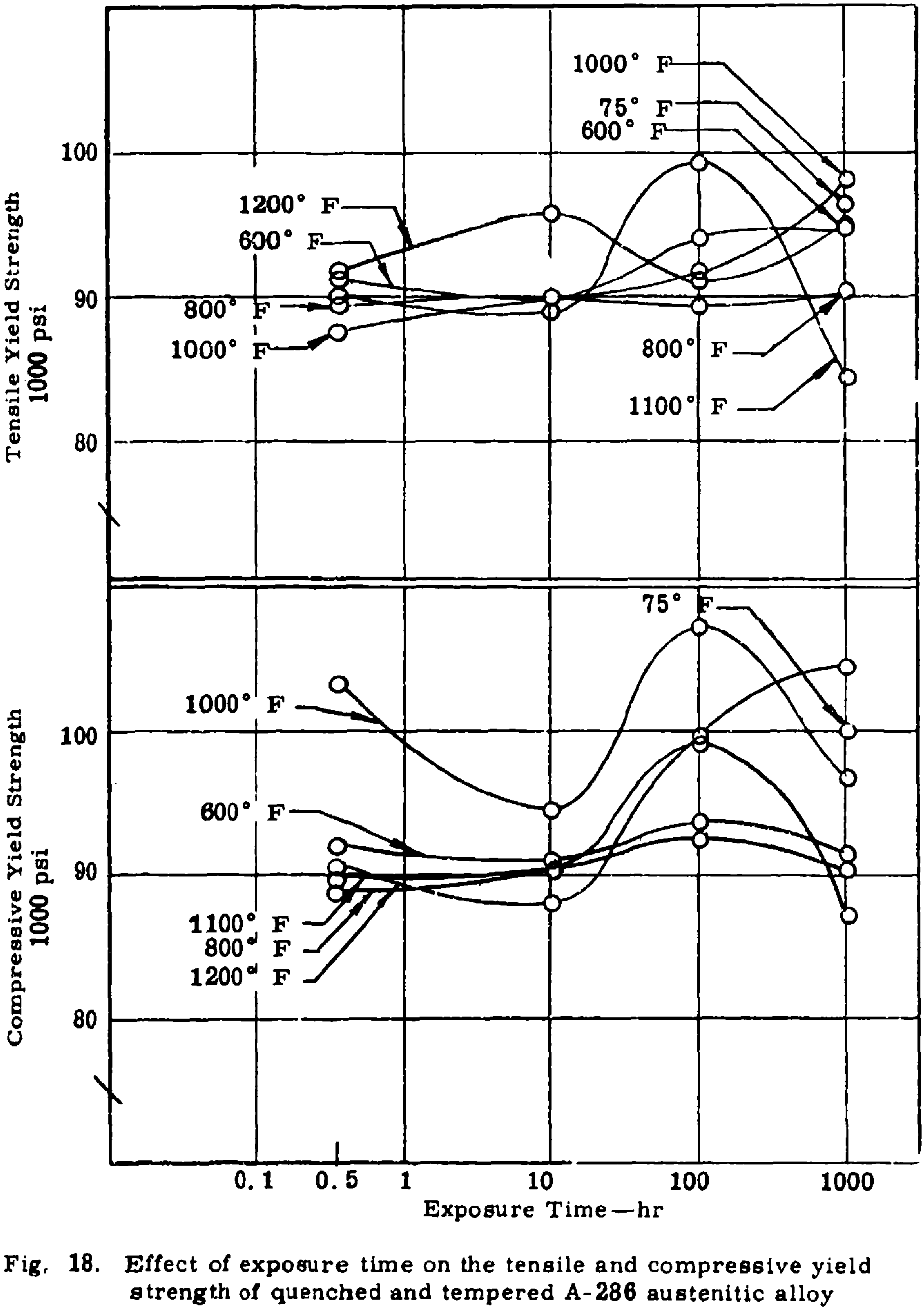


Fig. 18. Effect of exposure time on the tensile and compressive yield strength of quenched and tempered A-286 austenitic alloy sheet at different temperatures.

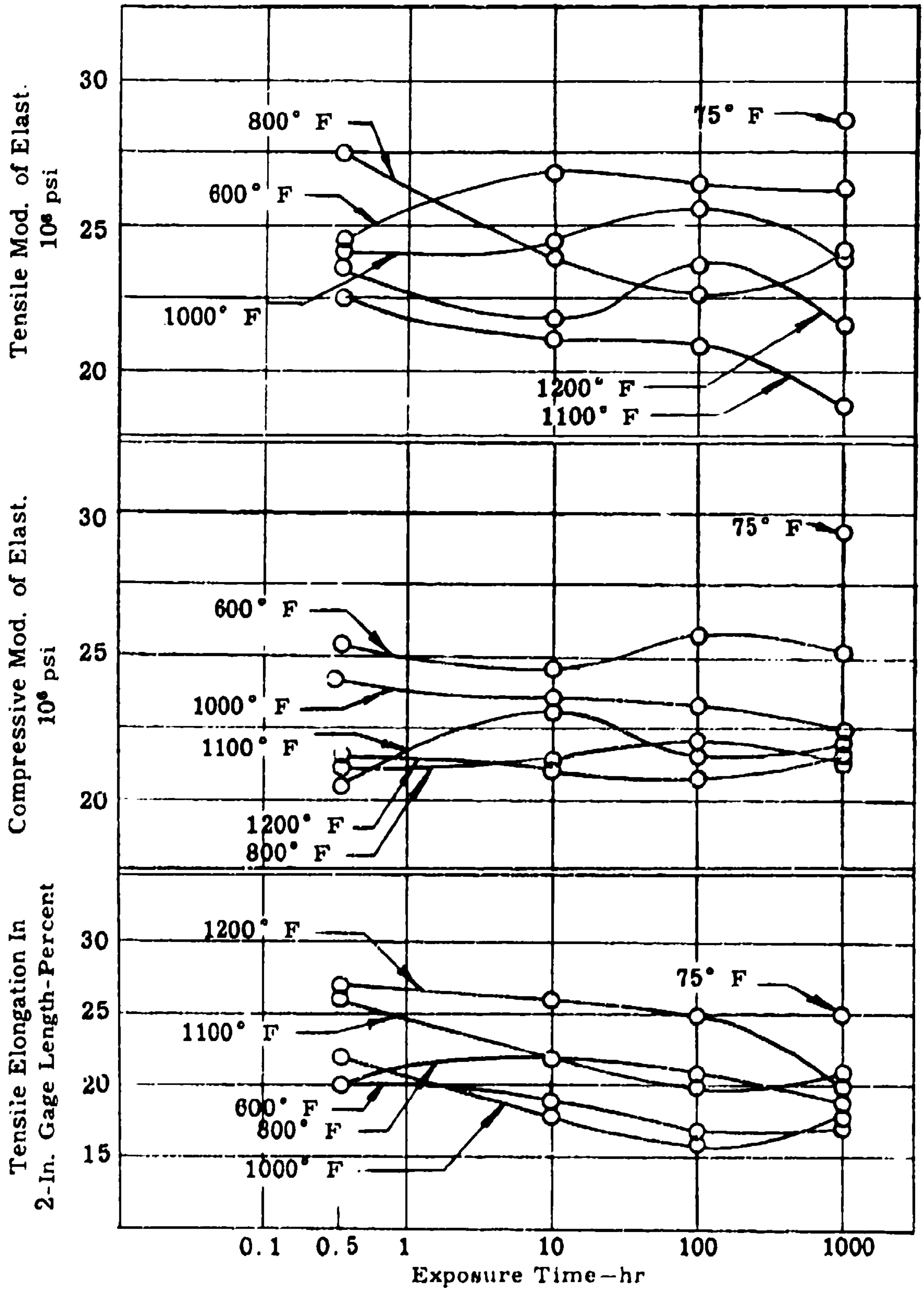


Fig. 19. Effect of exposure time on the tensile and compressive moduli of of elasticity and percent elongation of quenched and tempered A-286 austenitic alloy sheet at different temperatures.

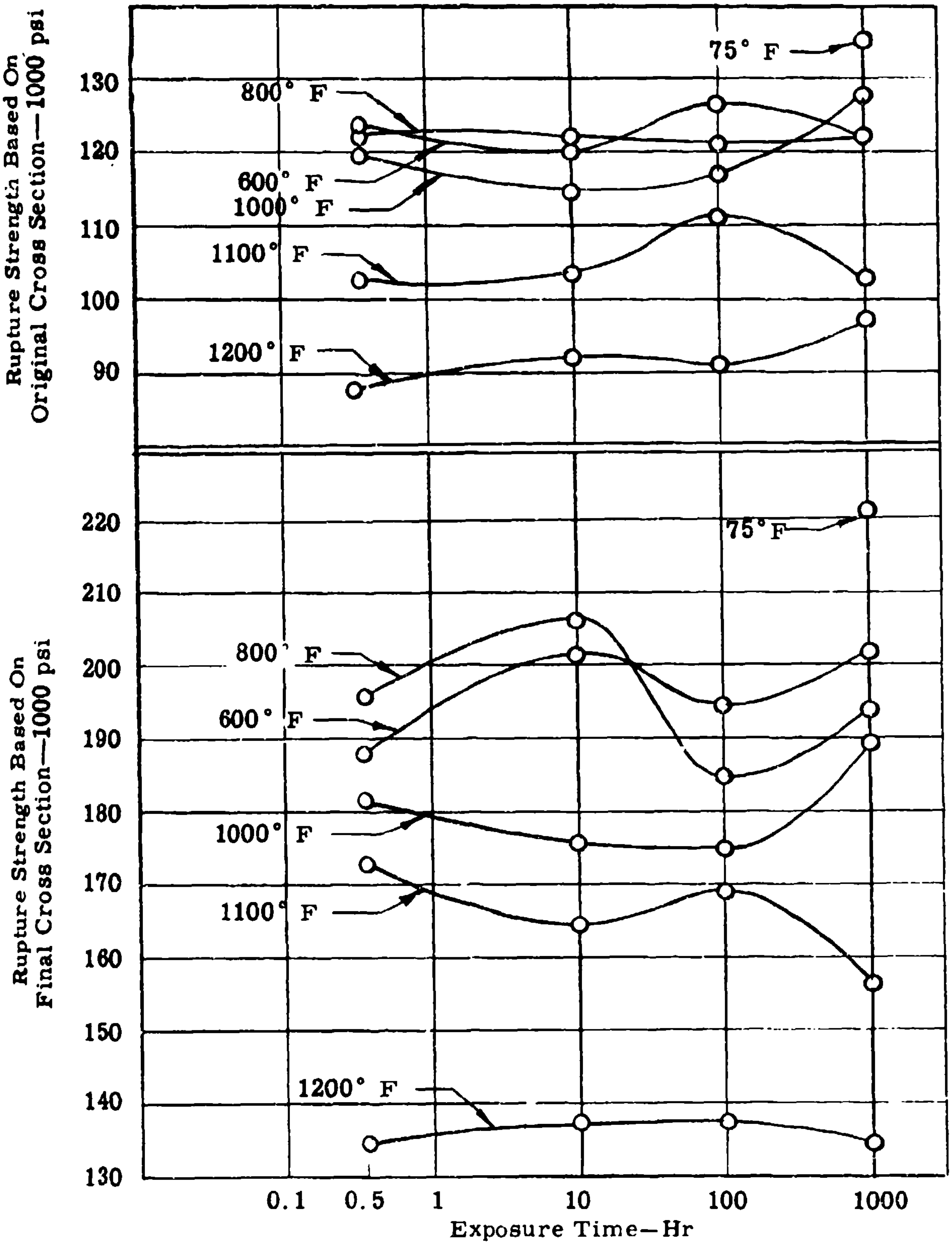


Fig. 20. Effect of exposure time on the tensile rupture strength of quenched and tempered A-286 austenitic alloy sheet at different temperatures.

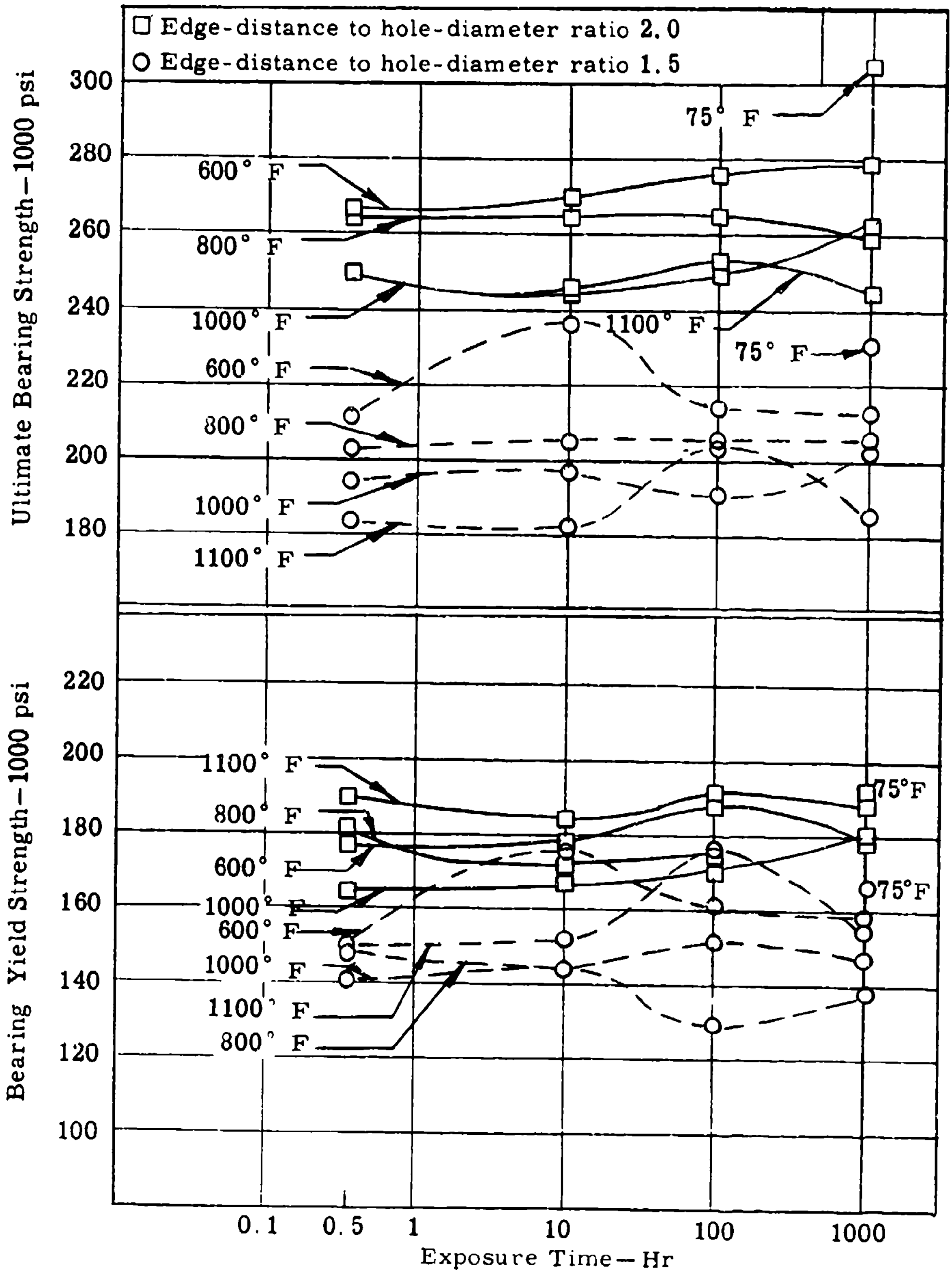


Fig. 21. Effect of exposure time on the bearing ultimate and yield strengths of quenched and tempered A-286 austenitic alloy sheet at different temperatures.

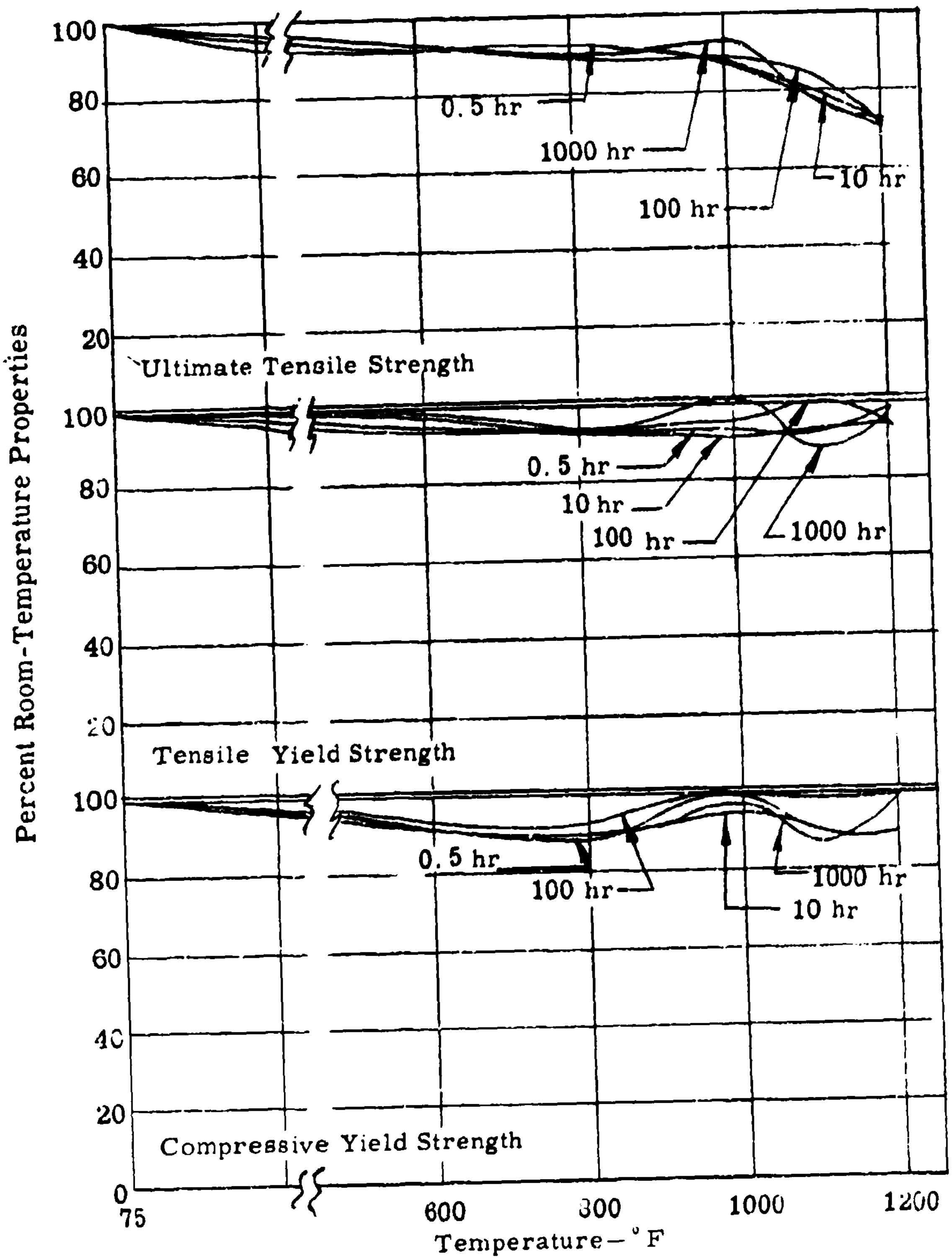


Fig. 22. Elevated-temperature strength properties as percent of room-temperature properties for quenched and tempered A-286 austenitic alloy sheet at different exposure times

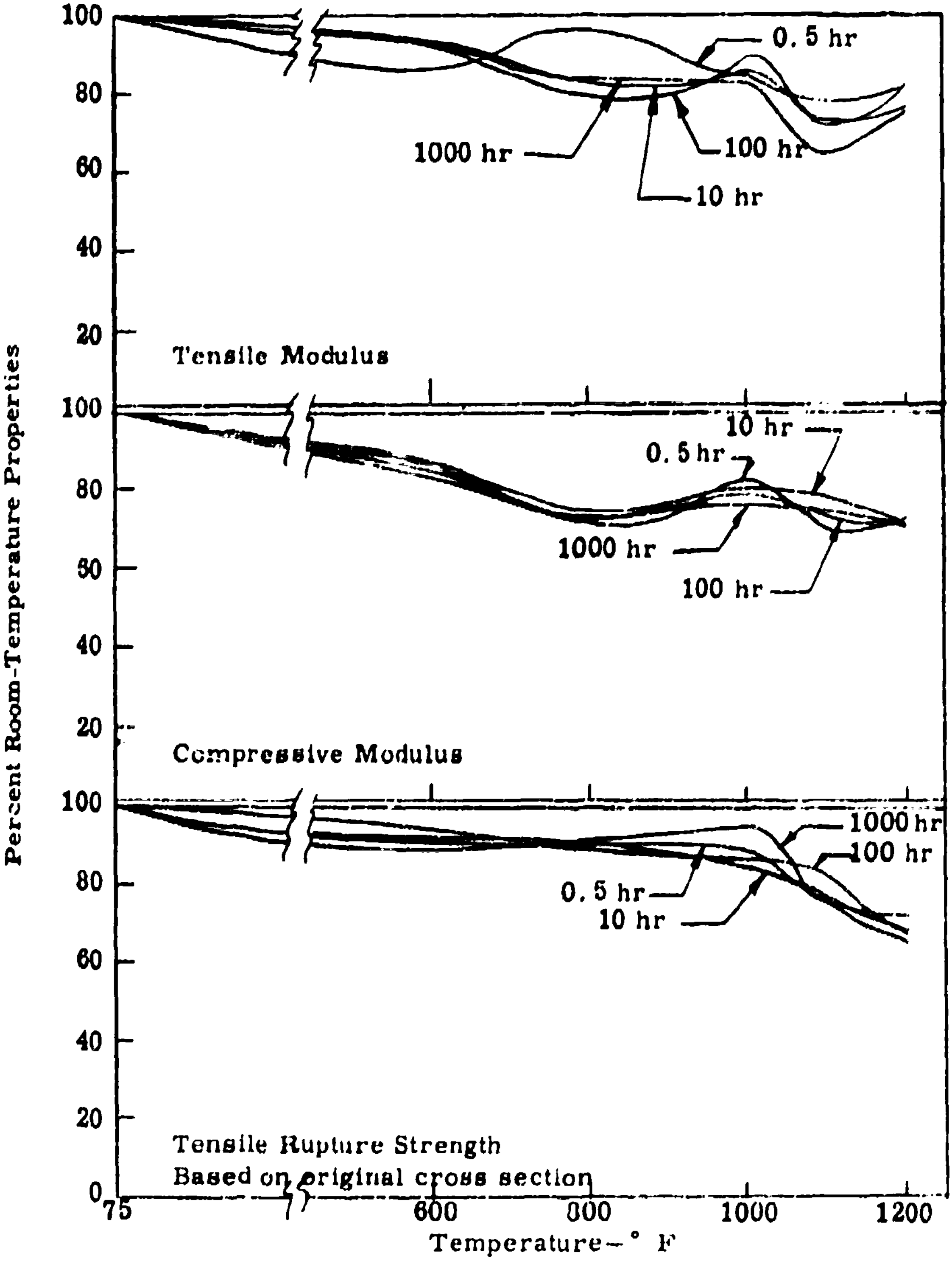


Fig. 23. Elevated-temperature properties as percent of room-temperature properties for quenched and tempered A-286 austenitic alloy sheet at different exposure times

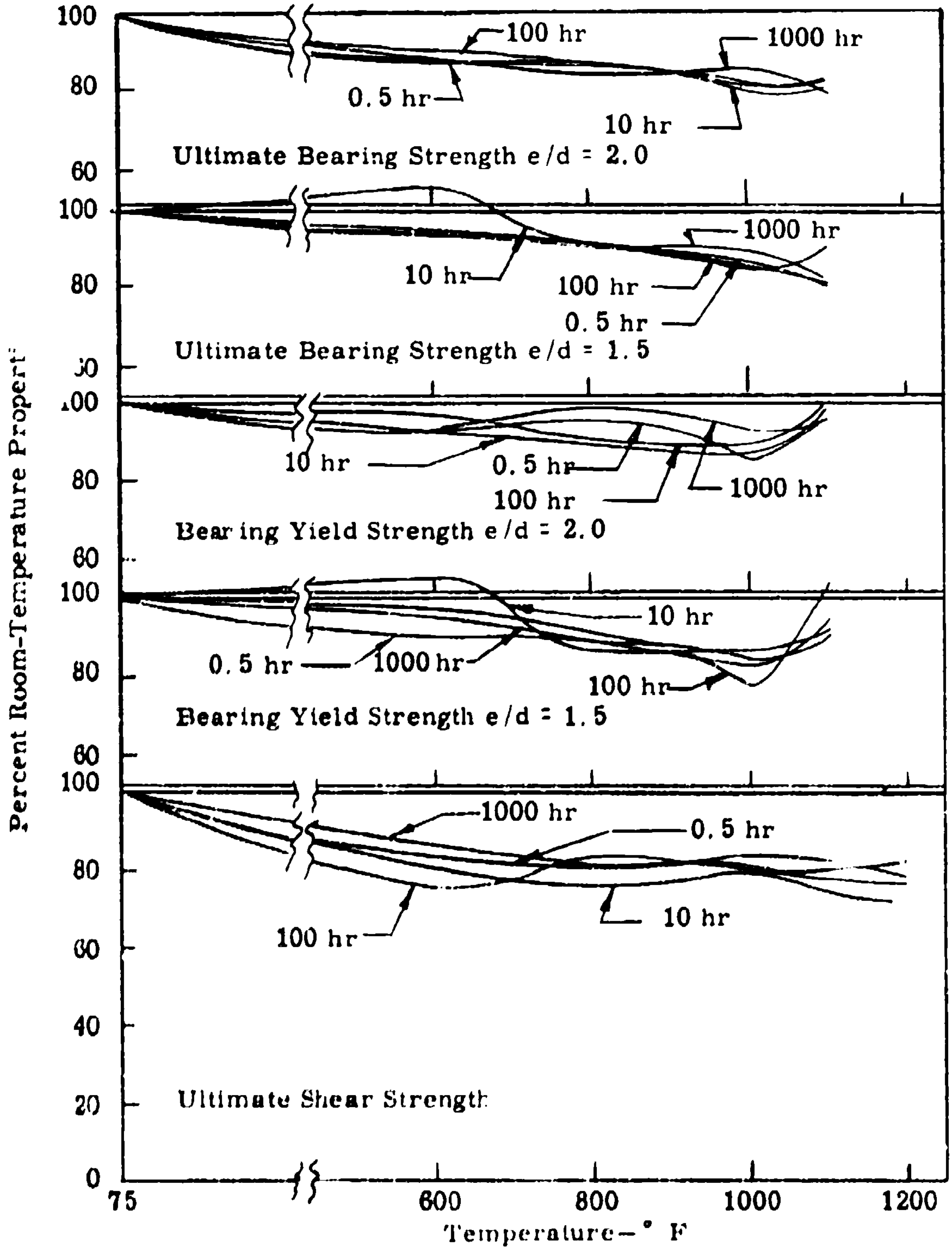


Fig. 24. Elevated-temperature strength properties as percent of room-temperature properties for quenched and tempered A-286 austenitic alloy sheet at different exposure times.

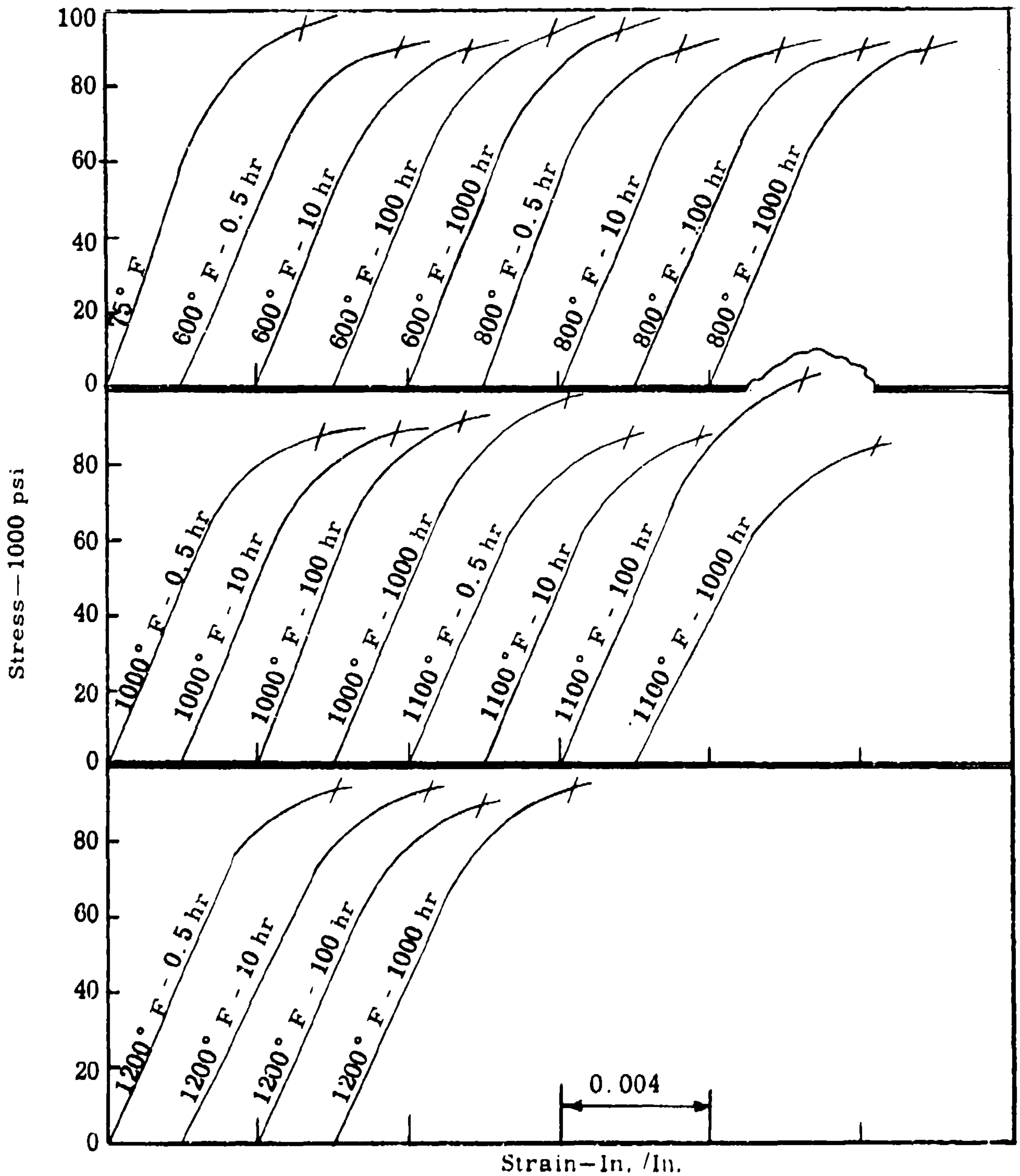


Fig. 25. Tensile stress-strain curves for quenched and tempered A-286 austenitic alloy sheet at various temperatures and exposure times.

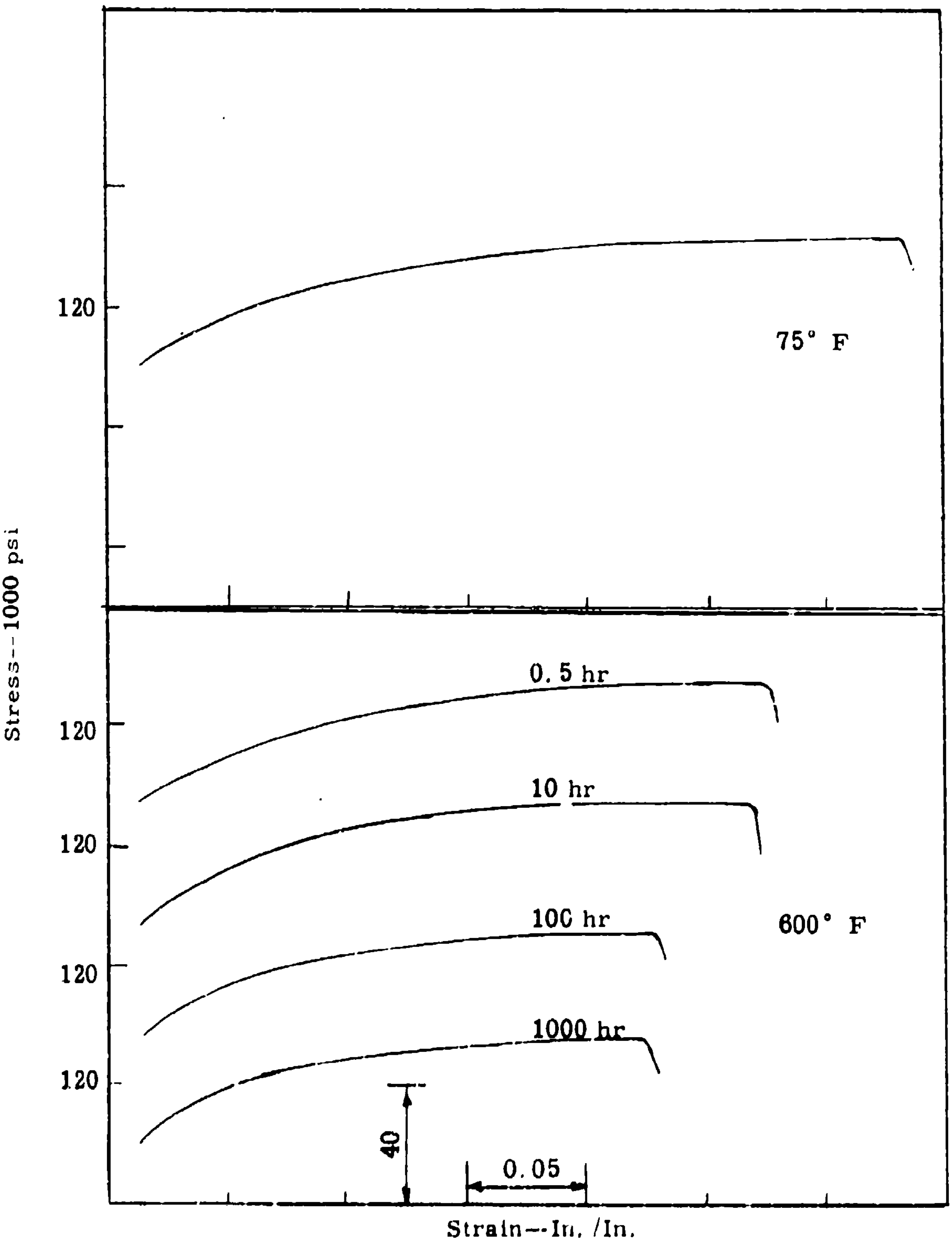


Fig. 26. Tensile postyield stress-strain curves for quenched and tempered A-286 austenitic alloy sheet at various temperatures and exposure times.

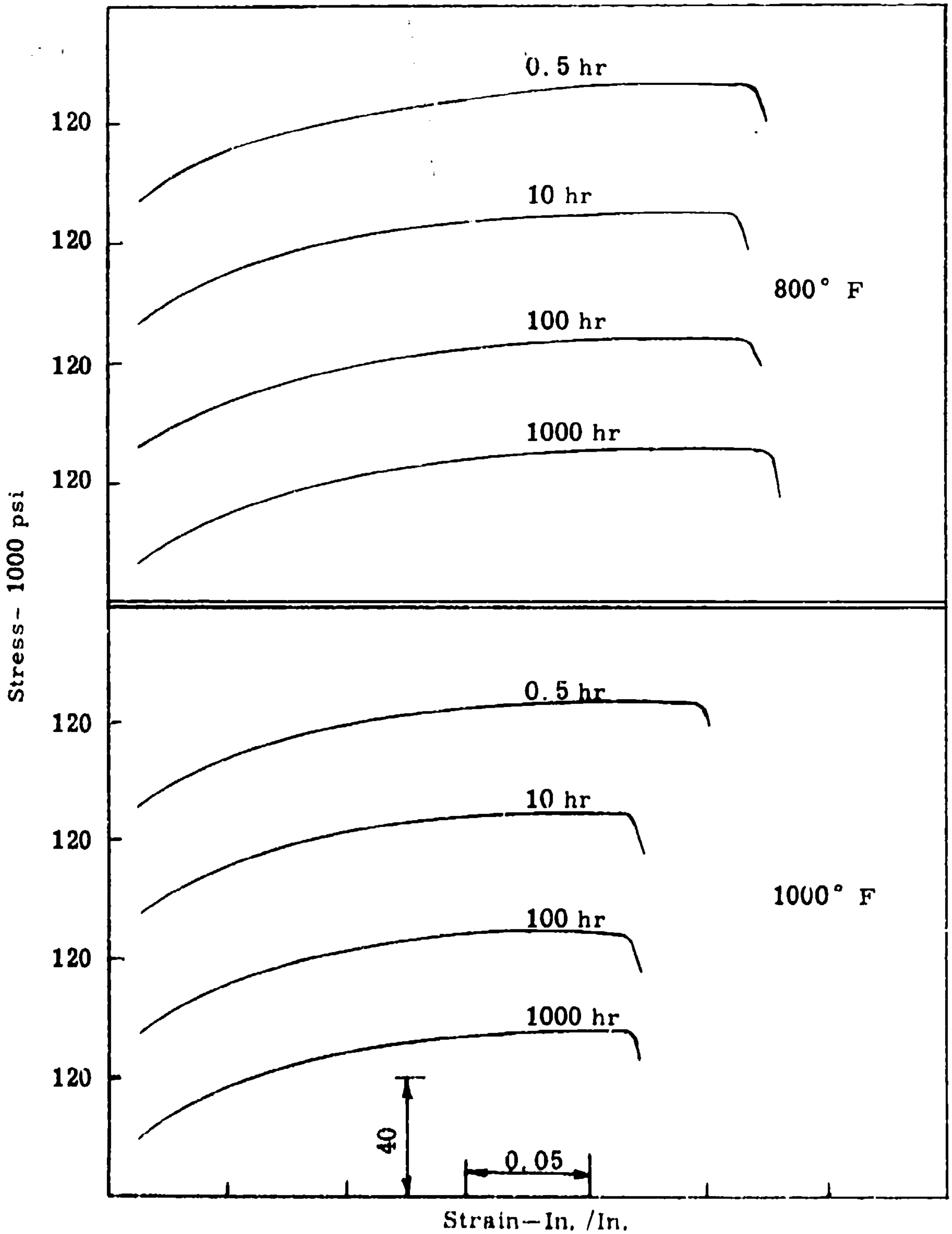


Fig. 27. Tensile postyield stress-strain curves for quenched and tempered A-286 austenitic alloy sheet at various temperatures and exposure times.

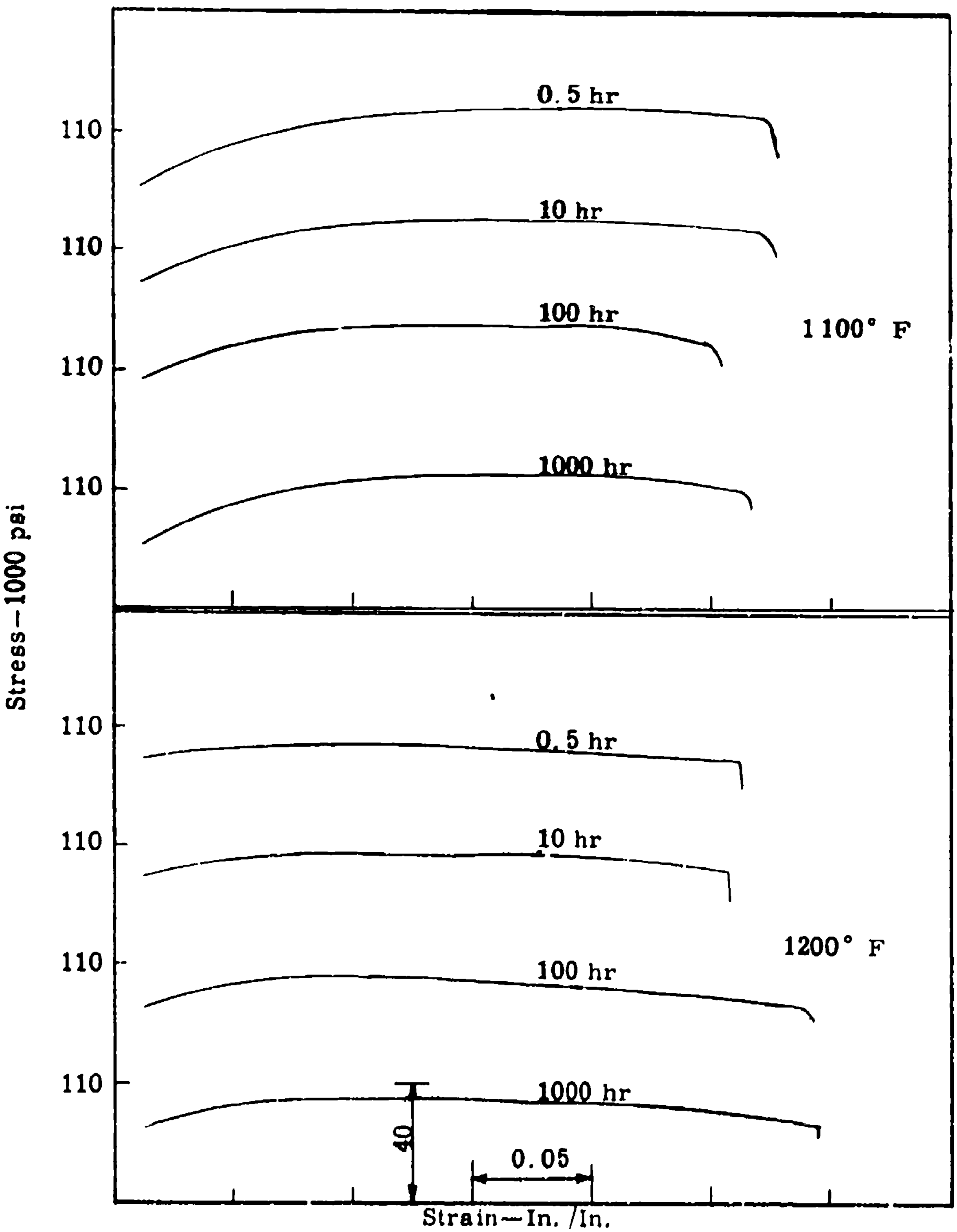


Fig. 28. Tensile postyield stress-strain curves for quenched and tempered A-286 austenitic alloy sheet at various temperatures and exposure times.

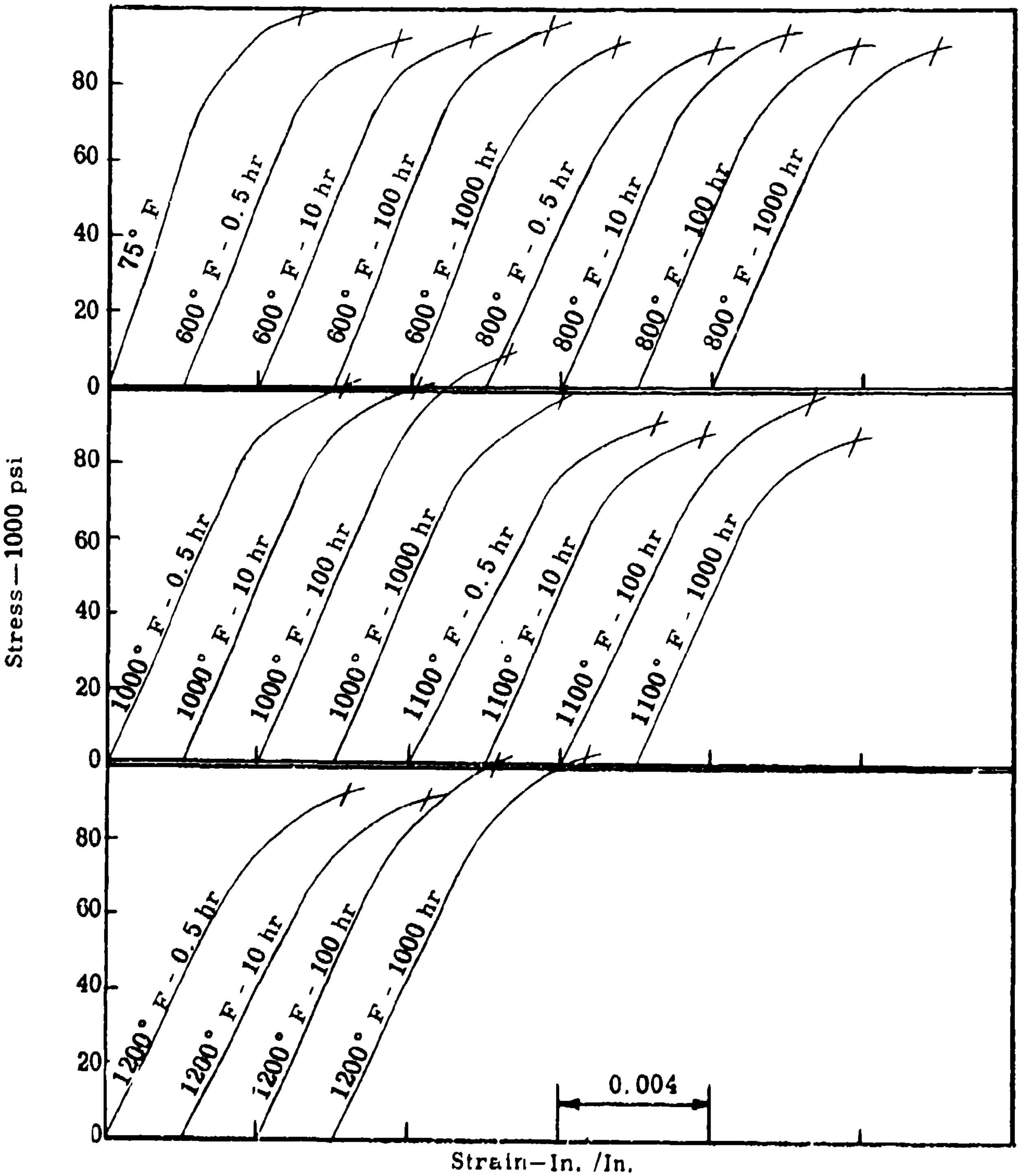


Fig. 29. Compressive stress-strain curves for quenched and tempered A-286 austenitic alloy sheet at various temperatures and exposure times.

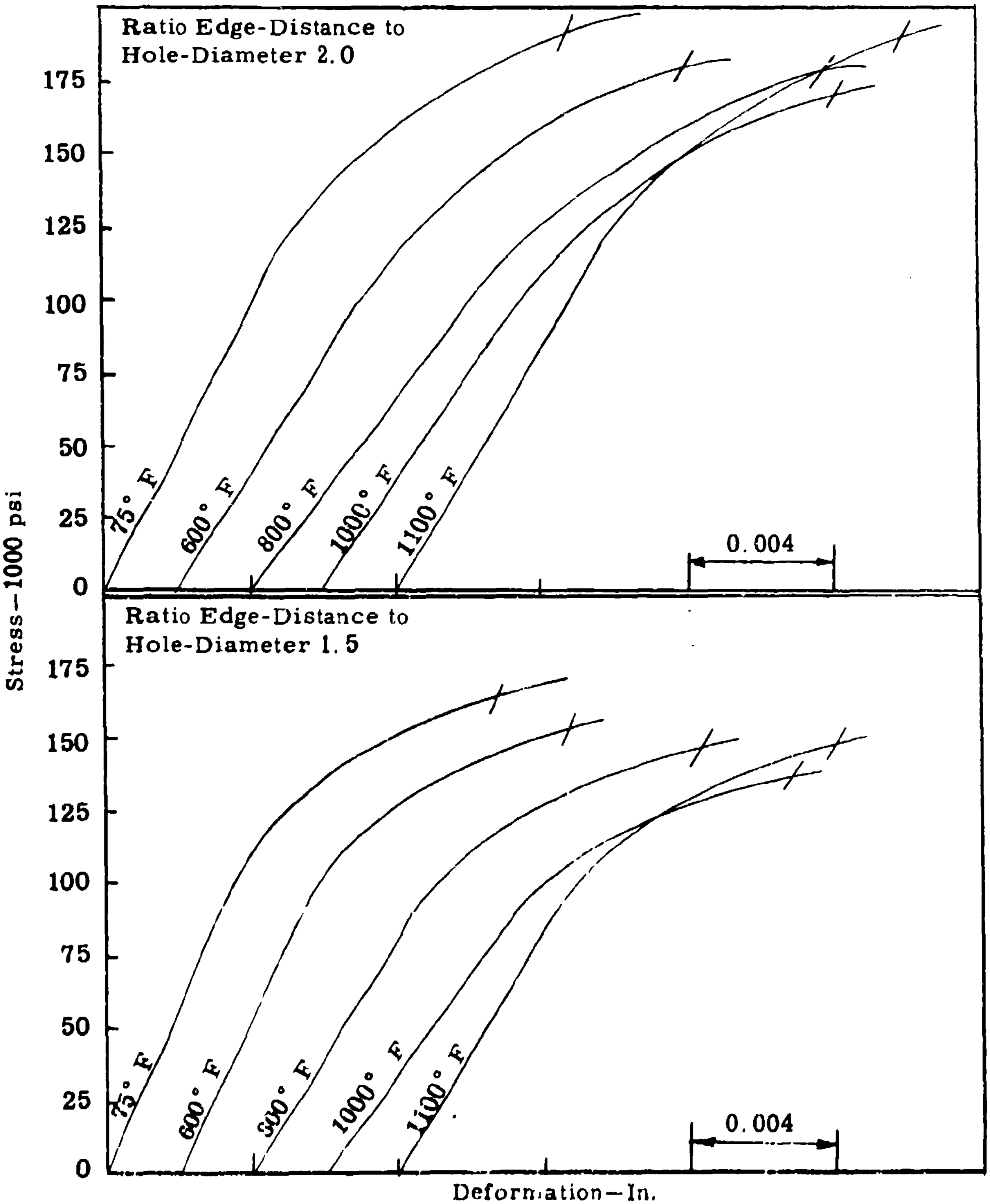


Fig. 30. Bearing stress-deformation curves for quenched and tempered A-286 austenitic alloy sheet at various temperatures and one-half hour exposure time

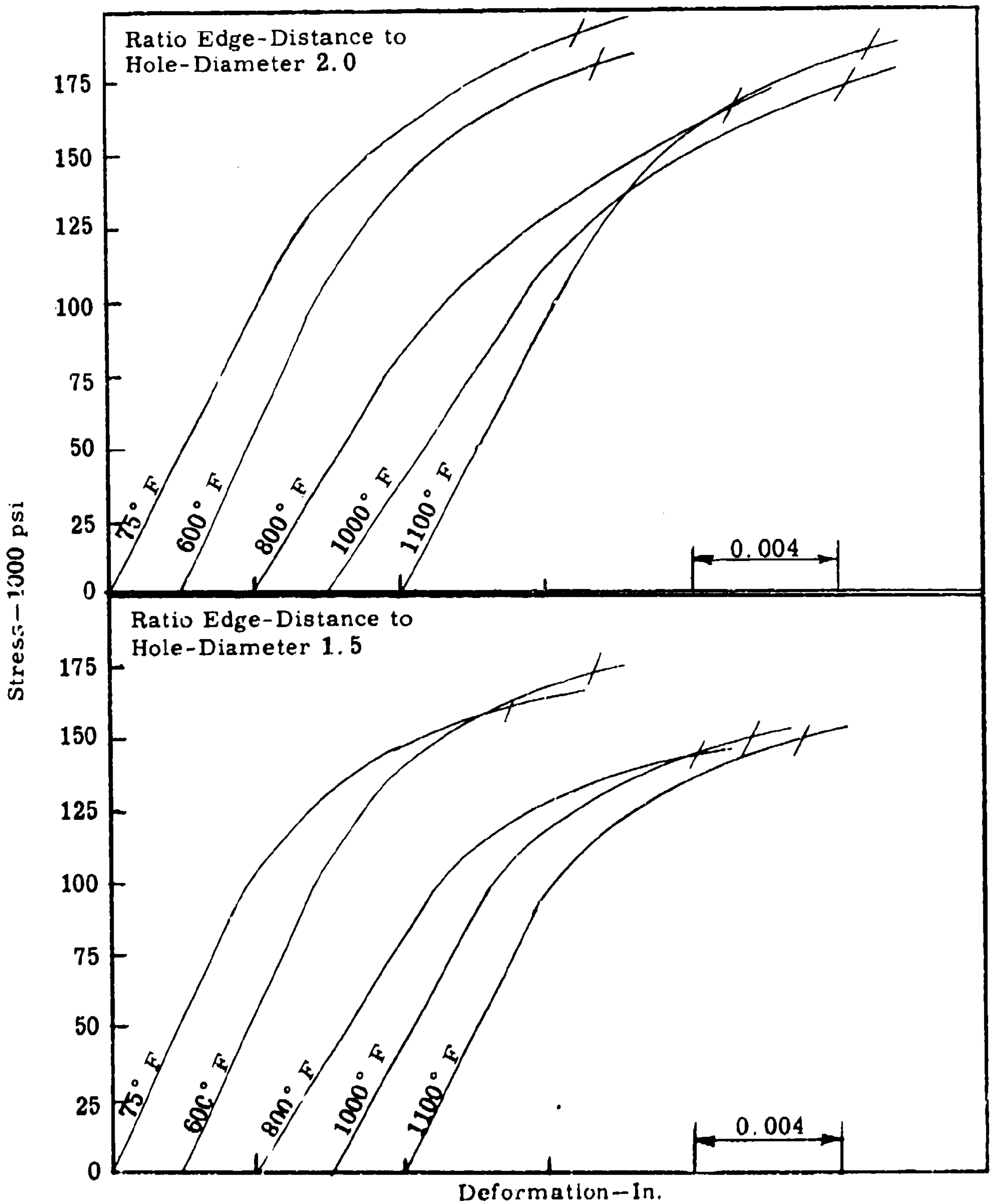


Fig. 31. Bearing stress-deformation curves for quenched and tempered A-286 austenitic alloy sheet at various temperatures and ten-hour exposure time.

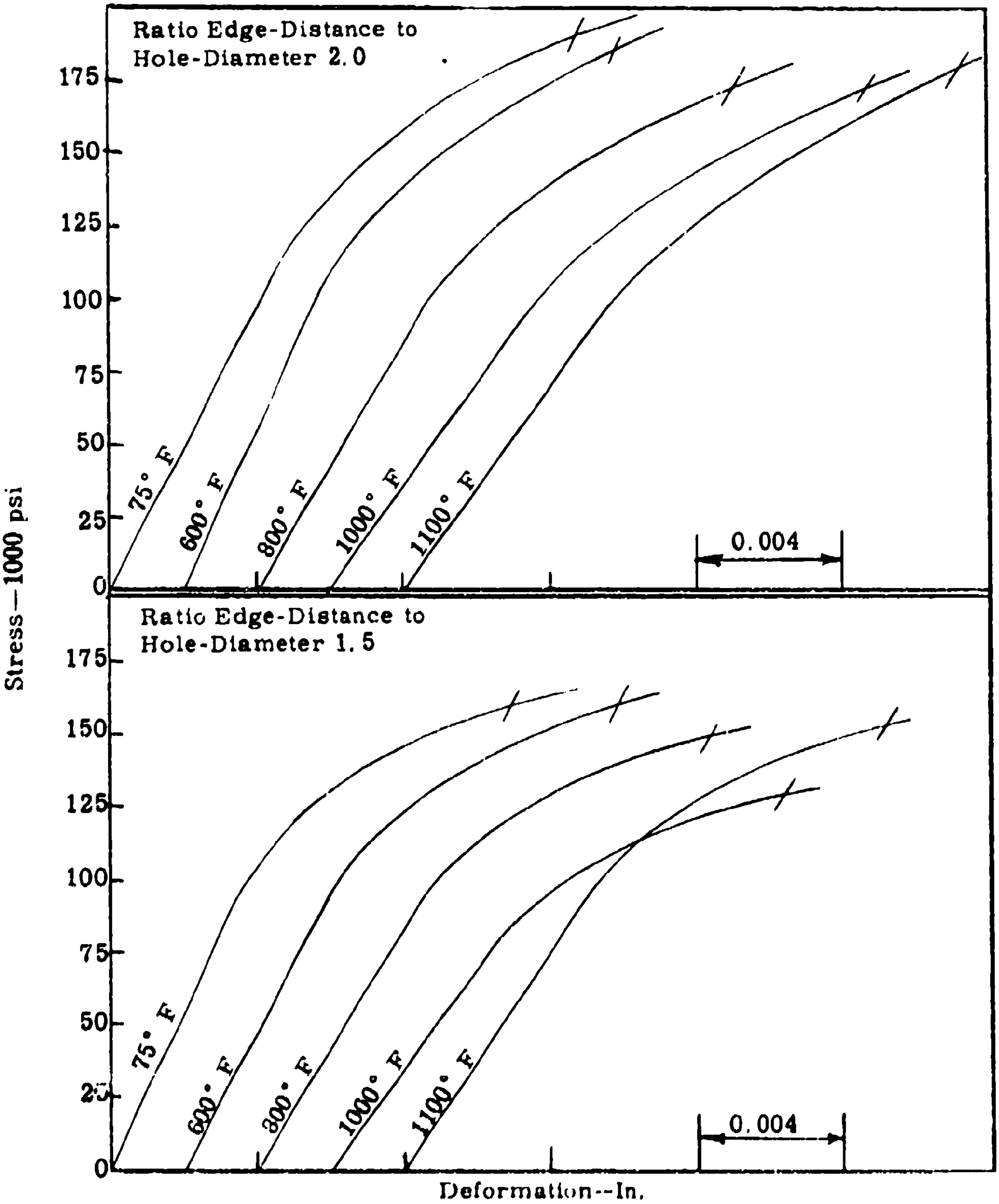


Fig. 32. Bearing stress-deformation curves for quenched and tempered A-286 austenitic alloy sheet at various temperatures and one-hundred-hour exposure time.

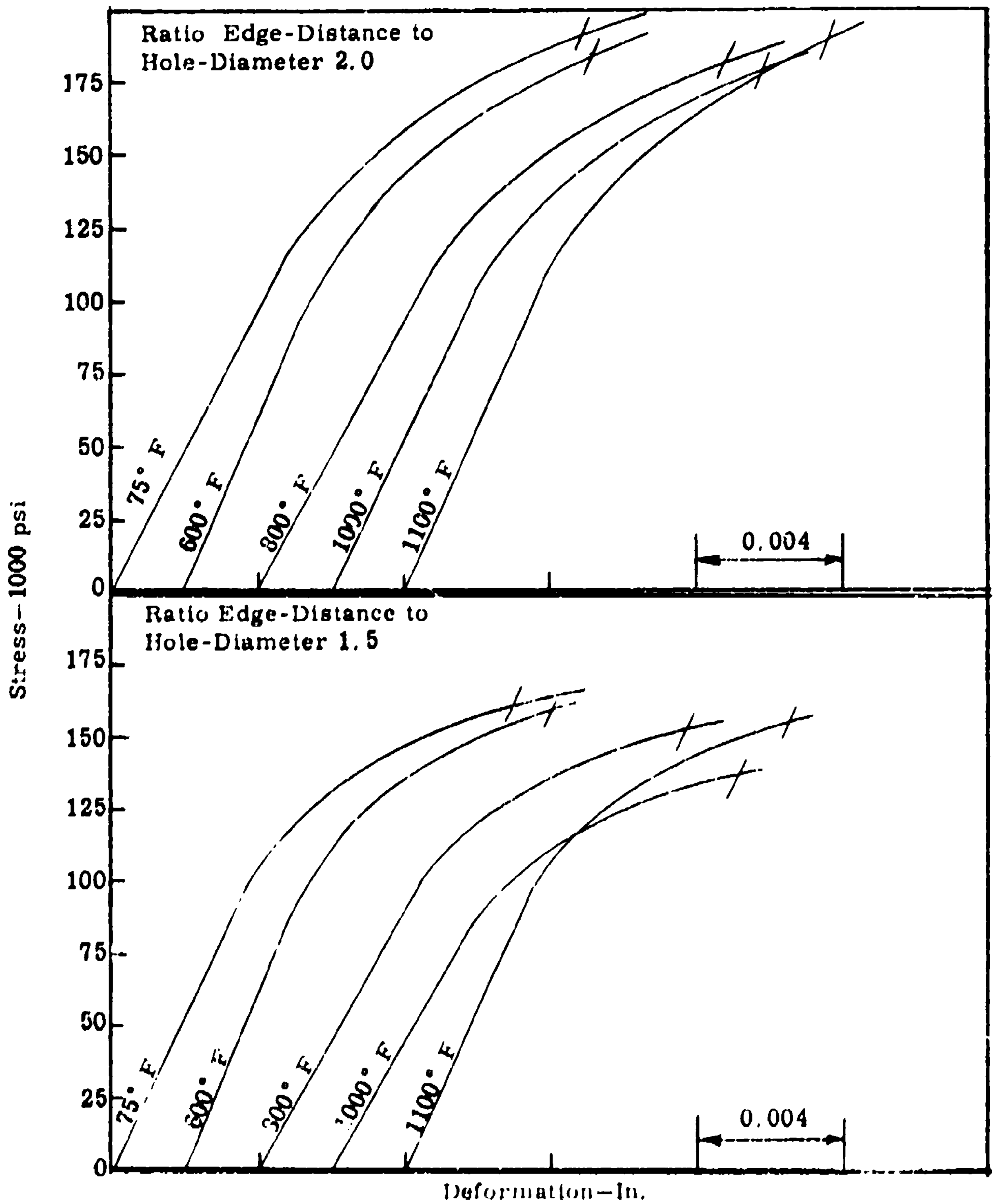


Fig. 33. Bearing stress-deformation curves for quenched and tempered A-286 austenitic alloy sheet at various temperatures and one-thousand-hour exposure time.

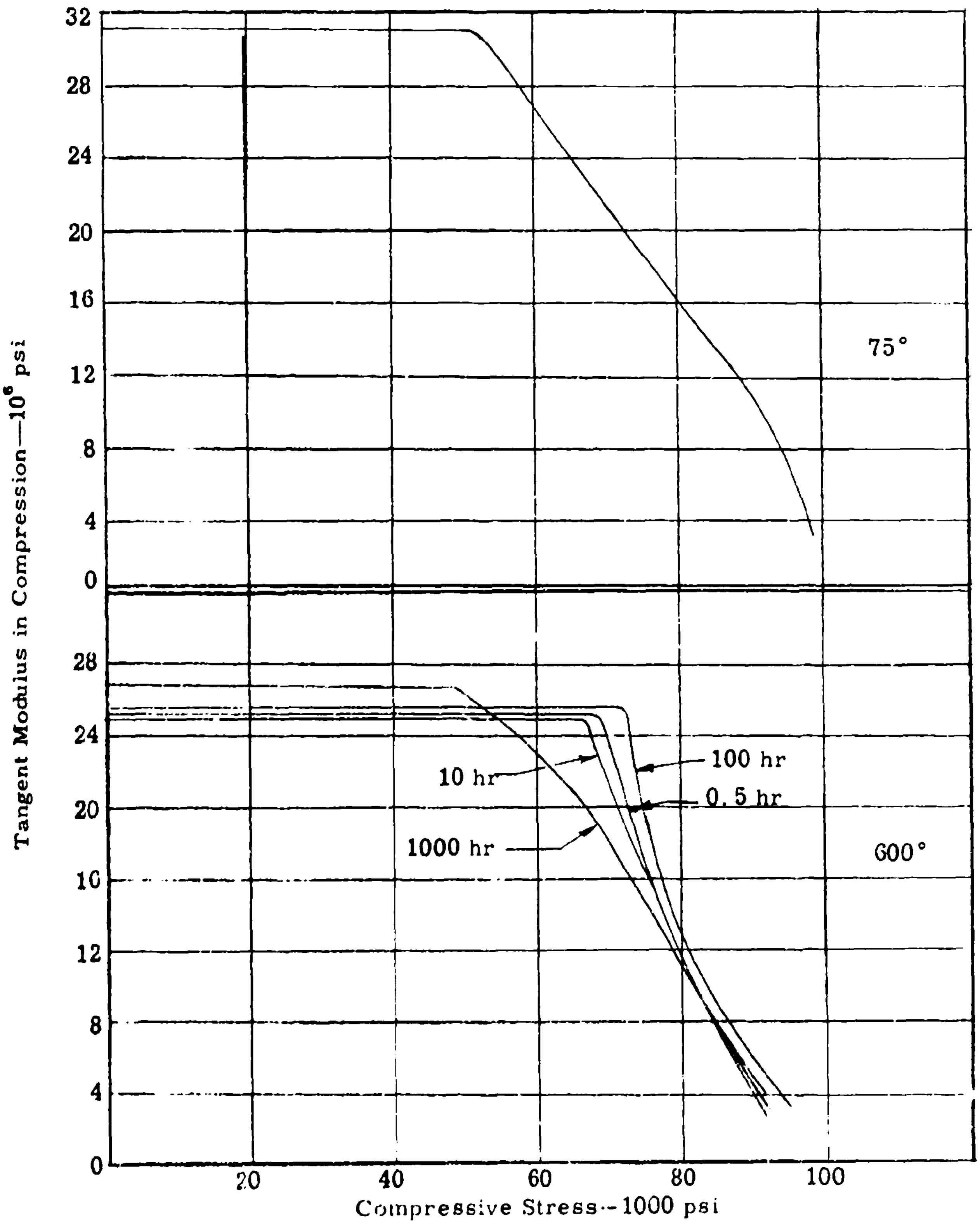


Fig. 34. Tangent-modulus vs. compressive-stress curves for quenched and tempered A-286 austenitic alloy sheet at 75° F and 600° F and different exposure times.

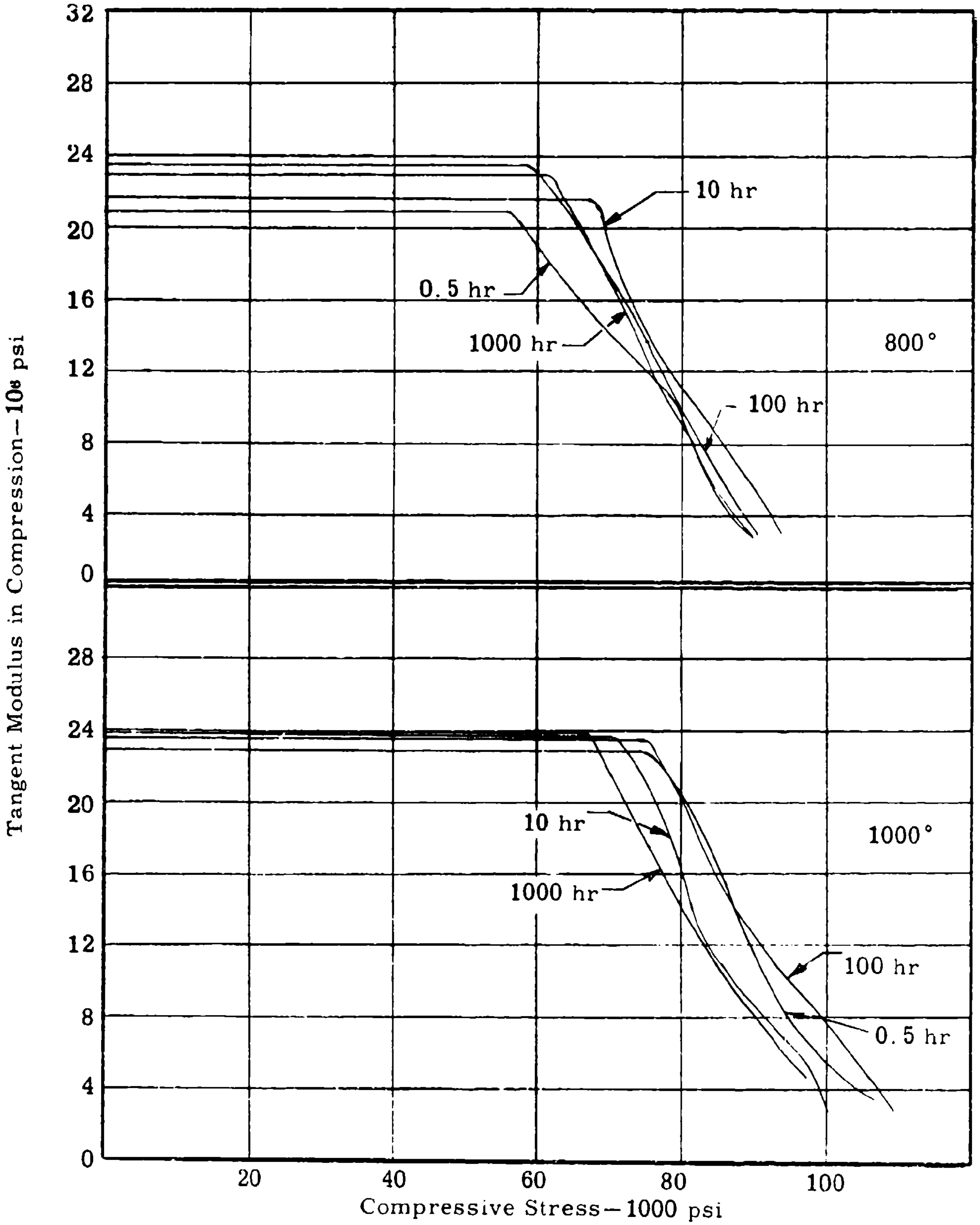


Fig. 35. Tangent-modulus vs. compressive stress-curves for quenched and tempered A-286 austenitic alloy sheet at 800° and 1000° and different exposure times.

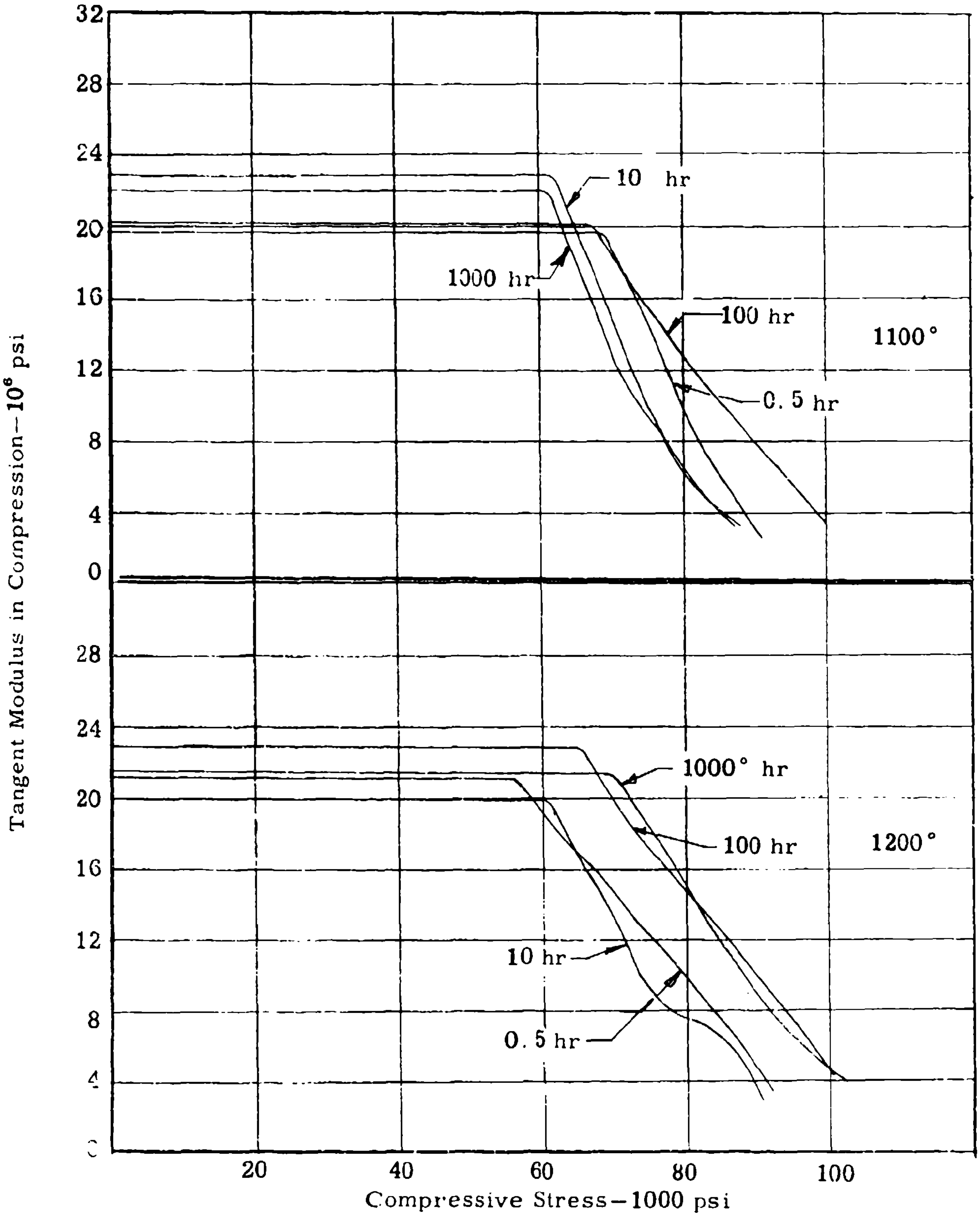


Fig. 56. Tangent-modulus vs. compressive-stress curves for quenched and tempered A-286 austenitic alloy sheet at 1100° F and 1200° F and different exposure times.

Table 4

**Tensile Properties of 0.062-In. A-286 Austenitic Alloy[4] Sheet at Different Temperatures and Holding Times**

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| RT | | 98.7 | 149.5 | 28.7 | 25 | 31 | – | – |
| | | 96.0 | 143.8 | 28.6 | 24 | 32 | 134.0 | 224.0 |
| | | 94.6 | 146.8 | 28.6 | 27 | 31 | 137.0 | 219.0 |
| Avg | | 96.4 | 146.7 | 28.6 | 25 | 31 | 135.5 | 221.5 |
| 600 | 0.5 | 91.5 | 135.0 | 24.3 | 19 | 33 | 124.0 | 176.0 |
| | | 90.5 | 136.0 | 24.5 | 20 | 34 | 126.0 | 191.0 |
| | | 91.5 | 135.0 | 24.6 | 20 | 34 | 122.0 | 197.0 |
| Avg | | 91.2 | 135.3 | 24.5 | 20 | 34 | 124.0 | 188.0 |
| 600 | 10 | 90.3 | 136.0 | 26.2 | 20 | 32 | 119.2 | 203.2 |
| | | 89.6 | 134.0 | 26.9 | 18 | 31 | 122.5 | 205.5 |
| | | 90.2 | 135.0 | 27.4 | 20 | 31 | 119.0 | 196.0 |
| Avg | | 90.0 | 135.0 | 26.8 | 19 | 31 | 120.2 | 201.6 |
| 600 | 100 | 97.2 | 139.5 | 27.7 | 18 | 33 | 133.2 | 197.0 |
| | | 95.4 | 138.6 | 25.2 | 18 | 32 | 124.0 | 190.0 |
| | | 90.0 | 132.0 | 26.6 | 16 | 33 | 123.4 | 197.0 |
| Avg | | 94.2 | 136.7 | 26.5 | 17 | 33 | 126.9 | 194.7 |
| 600 | 1000 | 93.5 | 137.0 | 24.2 | 18 | 33 | 120.5 | 206.0 |
| | | 95.0 | 138.0 | 27.8 | 18 | 32 | 120.5 | 186.5 |
| | | 96.0 | 137.0 | 26.8 | 16 | 34 | 125.5 | 214.0 |
| Avg | | 94.8 | 137.3 | 26.3 | 17 | 33 | 122.2 | 202.2 |

Table 4 (continued)

Tensile Properties of 0.062-In. A-286 Austenitic Alloy[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 800 | 0.5 | 89.5 | 133.5 | 27.2 | 20 | 32 | 122.4 | 189.5 |
| | | 89.5 | 133.5 | 27.9 | 19 | 34 | 122.4 | 210.0 |
| | | 89.5 | 133.5 | – | 20 | 34 | 122.4 | 187.5 |
| Avg | | 89.5 | 133.5 | 27.5 | 20 | 33 | 122.4 | 195.7 |
| 800 | 10 | 89.2 | 131.8 | 24.5 | 22 | 32 | 128.0 | 219.0 |
| | | 91.2 | 134.2 | 23.5 | 21 | 31 | 120.2 | 205.0 |
| | | 90.0 | 131.2 | 23.6 | 22 | 32 | 118.8 | 194.8 |
| Avg | | 90.1 | 132.4 | 23.9 | 22 | 32 | 122.3 | 206.3 |
| 800 | 100 | 90.5 | 134.0 | 23.1 | 21 | 29 | 121.2 | 188.8 |
| | | 88.8 | 130.5 | 21.5 | 21 | 32 | 121.8 | 188.5 |
| | | 88.8 | 129.2 | 23.2 | 20 | 32 | 120.5 | 178.0 |
| Avg | | 89.4 | 131.2 | 22.6 | 21 | 31 | 121.2 | 185.1 |
| 800 | 1000 | 90.0 | 130.0 | 22.5 | 20 | 31 | 123.0 | 194.0 |
| | | 90.0 | 132.0 | 24.7 | 19 | 32 | 117.6 | 186.0 |
| | | 91.7 | 135.0 | 25.4 | 19 | 32 | 120.0 | 202.5 |
| Avg | | 90.6 | 132.3 | 24.2 | 19 | 32 | 122.2 | 194.2 |
| 1000 | 0.5 | 86.5 | 127.5 | 23.2 | 22 | 34 | 124.0 | 199.0 |
| | | 87.5 | 127.5 | 25.2 | 22 | 34 | 119.2 | 169.0 |
| | | 89.5 | 127.0 | 24.2 | 22 | 34 | 116.0 | 177.0 |
| Avg | | 87.8 | 127.3 | 24.2 | 22 | 34 | 119.7 | 181.7 |

Table 4 (continued)

Tensile Properties of 0.062-In. A-286 Austenitic Alloy[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 1000 | 10 | 89.0 | 130.0 | 23.0 | 18 | 31 | 110.0 | 167.0 |
| | | 91.5 | 130.0 | 25.5 | 18 | 31 | 119.0 | 177.0 |
| | | 89.0 | 129.3 | 25.0 | 17 | 32 | 116.0 | 183.0 |
| Avg | | 89.8 | 129.8 | 24.5 | 18 | 31 | 115.0 | 175.7 |
| 1000 | 100 | 90.7 | 129.8 | 26.3 | 16 | 32 | 116.5 | 177.2 |
| | | 92.4 | 130.5 | 22.7 | 16 | 31 | 117.4 | 178.2 |
| | | 92.2 | 131.6 | 27.8 | 16 | 31 | 117.2 | 170.0 |
| Avg | | 91.3 | 130.6 | 25.6 | 16 | 31 | 117.0 | 175.1 |
| 1000 | 1000 | 98.0 | 138.0 | 24.5 | 18 | 33 | 130.0 | 193.0 |
| | | 98.0 | 137.2 | 23.5 | 18 | 34 | 126.0 | 187.0 |
| | | 98.5 | 136.8 | 23.8 | 18 | 34 | 128.0 | 189.0 |
| Avg | | 98.2 | 137.3 | 23.9 | 18 | 34 | 128.0 | 189.7 |
| 1100 | 0.5 | 87.5 | 116.0 | 22.4 | 28 | 29 | 99.6 | 177.5 |
| | | 90.0 | 117.5 | 21.7 | 24 | 29 | 103.0 | 181.0 |
| | | 93.5 | 119.0 | 23.4 | 26 | 29 | 106.0 | 160.0 |
| Avg | | 90.3 | 117.5 | 22.5 | 26 | 29 | 102.8 | 172.8 |
| 1100 | 10 | 88.0 | 117.0 | 20.2 | 22 | 26 | 102.5 | 169.5 |
| | | 87.5 | 118.5 | 23.0 | 23 | 28 | 101.0 | 149.0 |
| | | 92.0 | 120.0 | 20.1 | 22 | 28 | 108.0 | 175.0 |
| Avg | | 89.2 | 118.5 | 21.1 | 22 | 27 | 103.8 | 164.5 |

Table 4 (continued)

Tensile Properties of 0.62-In. A-286 Austenitic Alloy[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 1100 | 100 | 103.0 | 125.5 | 22.2 | 20 | 36 | 111.0 | 183.0 |
| | | 96.0 | 126.0 | 19.9 | 20 | 34 | 113.0 | 167.5 |
| | | 99.7 | 126.0 | 20.7 | 21 | 33 | 110.0 | 157.3 |
| Avg | | 99.5 | 125.8 | 20.9 | 20 | 34 | 111.3 | 169.2 |
| 1100 | 1000 | 85.2 | 115.0 | 19.0 | 20 | 31 | 103.8 | 153.2 |
| | | 85.3 | 116.5 | 19.0 | 20 | 33 | 103.2 | 166.0 |
| | | 84.2 | 113.2 | 18.5 | 22 | 30 | 101.5 | 150.5 |
| Avg | | 84.9 | 114.9 | 18.8 | 21 | 31 | 102.8 | 156.5 |
| 1200 | 0.5 | 89.0 | 102.0 | 23.1 | 31 | 28 | 86.5 | 132.9 |
| | | 92.0 | 103.0 | 24.4 | 25 | 30 | 91.1 | 136.5 |
| | | 94.5 | 103.5 | 23.0 | 27 | 30 | 86.5 | 132.9 |
| Avg | | 91.8 | 102.8 | 23.5 | 27 | 29 | 88.0 | 134.1 |
| 1200 | 10 | 94.4 | 106.8 | 20.7 | 27 | 33 | 92.8 | 138.5 |
| | | 97.5 | 107.0 | 21.5 | 24 | 32 | 92.6 | 136.5 |
| | | — | 105.5 | 23.5 | 27 | 32 | 91.4 | 136.5 |
| Avg | | 95.9 | 106.4 | 21.9 | 26 | 32 | 92.2 | 137.1 |
| 1200 | 100 | 91.2 | 104.6 | 22.7 | 26 | 34 | 84.4 | 137.3 |
| | | 92.1 | 106.0 | 25.7 | 23 | 34 | 92.8 | 140.5 |
| | | 90.3 | 106.5 | 22.7 | 25 | 35 | 96.8 | 134.5 |
| Avg | | 91.2 | 105.7 | 23.7 | 25 | 34 | 91.3 | 137.4 |

Table 4 (continued)

Tensile Properties of 0.062-In. A-286 Austenitic Alloy[4] Sheet at Different Temperatures and Holding Times

| Temp ° F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 1200 | 1000 | 94.8 | 110.8 | 21.5 | 18 | 36 | 102.1 | 142.5 |
| | | 96.2 | 106.2 | 22.4 | 22 | 35 | 97.0 | 133.5 |
| | | 94.2 | 104.5 | 21.1 | 20 | 35 | 92.8 | 127.6 |
| Avg | | 95.0 | 107.1 | 21.6 | 20 | 35 | 97.3 | 134.5 |

1. Hardness determinations made at room temperature after tests.
2. Rupture strength based on original cross section.
3. Rupture strength based on final cross section.
4. Heat treatment — 1800° F 1 hr argon atmosphere, O.Q., 1325° F 16 hr, A. C.

Table 5

Tensile Strength of 3/16-In. A-286 Austenitic Alloy[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard[2] RC | UTS 1000 psi | Hard[2] RC | UTS 1000 psi | Hard[2] RC |
| RT | | | | | | | 147.0 | 30 |
| | | | | | | | 150.1 | 31 |
| | | | | | | | 145.7 | 30 |
| | | | | | | | 146.7 | 30 |
| Avg | | | | | | | 147.4 | 30 |
| 600 | 135.3 | 30 | 136.5 | 33 | 138.0 | 33 | 144.0 | 32 |
| | 136.5 | 30 | 135.2 | 32 | 138.4 | 32 | 141.0 | 32 |
| | 135.9 | 31 | 134.7 | 31 | 138.2 | 32 | 143.5 | 32 |
| | 138.2 | 30 | 133.5 | 31 | – | – | 144.2 | 32 |
| Avg | 136.5 | 30 | 135.0 | 32 | 138.2 | 32 | 143.2 | 32 |
| 800 | 131.6 | 31 | 133.5 | 34 | 132.5 | 34 | 131.5 | 33 |
| | 131.2 | 29 | 134.0 | 34 | 136.5 | 34 | 134.0 | 33 |
| | 132.9 | 30 | 134.0 | 33 | 133.0 | 34 | 132.0 | 33 |
| | 132.8 | 31 | 133.0 | 33 | 132.5 | 34 | 132.0 | 33 |
| Avg | 132.1 | 30 | 133.6 | 33 | 133.6 | 34 | 132.4 | 33 |

Table 5 (continued)

Tensile Strength of 3/16-In. A-286 Austenitic Alloy[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC |
| 1000 | 124.8 | 30 | 129.2 | 31 | 128.3 | 34 | 136.0 | 35 |
| | 124.0 | 31 | 128.2 | 31 | 128.5 | 34 | 136.0 | 35 |
| | 125.0 | 29 | 129.3 | 31 | 129.0 | 34 | 136.0 | 35 |
| | 130.0 | 30 | 127.0 | 31 | – | – | – | – |
| Avg | 125.8 | 30 | 128.4 | 31 | 128.6 | 34 | 136.0 | 35 |
| 1100 | 119.2 | 28 | 121.0 | 27 | 125.4 | 32 | 117.3 | 28 |
| | 119.8 | 29 | 118.0 | 28 | 128.0 | 32 | 115.8 | 29 |
| | 120.2 | 28 | 122.0 | 28 | 128.0 | 32 | 116.0 | 29 |
| | 119.7 | 28 | 120.3 | 28 | 127.1 | 32 | 116.5 | 29 |
| 1200 | 102.0 | 29 | 107.2 | 30 | 108.7 | 33 | 106.5 | 35 |
| | 102.0 | 28 | 107.5 | 31 | 109.0 | 35 | 108.6 | 35 |
| | 102.5 | 29 | 109.0 | 30 | 108.5 | 33 | 109.2 | 33 |
| | 102.2 | 29 | 107.9 | 30 | 108.7 | 34 | 108.1 | 34 |

1. Ultimate tensile strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment — 1800° F 1 hr Argon atmosphere, O. Q., 1325° F 16 hr, A. C.

Table 6

Compressive Properties of 0.062-In. A-286 Austenitic Alloy[3] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | CYS[1] 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| RT | | | | | | | | | | 99.0 | 28.6 | 31 |
| | | | | | | | | | | 98.5 | 31.2 | 31 |
| | | | | | | | | | | 102.5 | 28.4 | 30 |
| Avg | | | | | | | | | | 100.0 | 29.4 | 31 |
| 600 | 91.8 | 25.0 | 30 | 91.8 | 24.8 | 31 | 94.5 | 25.5 | 31 | 90.5 | 26.5 | 33 |
| | 91.0 | 24.8 | 29 | 89.5 | 24.1 | 31 | 93.5 | 26.3 | 32 | 92.0 | 22.6 | 32 |
| | 93.5 | 26.5 | 30 | 91.6 | 25.0 | 29 | 93.5 | 25.5 | 32 | 92.0 | 26.5 | 32 |
| Avg | 92.1 | 25.4 | 30 | 91.0 | 24.6 | 30 | 93.8 | 25.8 | 32 | 91.5 | 25.2 | 32 |
| 800 | 89.2 | 22.4 | 30 | 90.8 | 20.0 | 31 | 90.0 | 23.5 | 31 | 91.4 | 23.8 | 30 |
| | 88.2 | 20.1 | 30 | 86.4 | 23.0 | 31 | 93.6 | 24.0 | 32 | 90.0 | 17.6 | 29 |
| | 89.3 | 20.8 | 31 | 93.6 | 21.5 | 29 | 94.0 | 18.8 | 31 | 89.5 | 22.8 | 30 |
| Avg | 88.9 | 21.1 | 30 | 90.3 | 21.5 | 30 | 92.5 | 22.1 | 31 | 90.3 | 21.4 | 30 |
| 1000 | 102.0 | 25.7 | 31 | 96.0 | 23.5 | 31 | 107.0 | 23.8 | 31 | 97.3 | 23.8 | 34 |
| | 101.0 | 23.9 | 30 | 87.7 | – | 31 | 106.0 | 22.7 | 31 | 96.4 | 21.2 | 34 |
| | 106.5 | 22.9 | 31 | 100.0 | 23.7 | 30 | 109.0 | 23.5 | 30 | – | – | – |
| Avg | 103.2 | 24.2 | 31 | 94.6 | 23.6 | 31 | 107.3 | 23.3 | 31 | 96.8 | 22.5 | 34 |

Table 6 (continued)

Compressive Properties of 0.062-In. A-286 Austenitic Alloy[3] Plate at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp ° F | CYS[1] 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| 1100 | 90.5 | 19.7 | 31 | 87.5 | 22.8 | 30 | 99.7 | 20.2 | 35 | 90.2 | 22.8 | 32 |
| | 90.5 | 22.0 | 32 | 90.2 | 23.5 | 31 | 96.6 | – | 36 | 86.5 | 21.9 | 32 |
| | 88.5 | 19.7 | 32 | 93.0 | 22.9 | 30 | 101.5 | 23.0 | 35 | 85.3 | 21.7 | 32 |
| Avg | 89.8 | 20.5 | 32 | 90.2 | 23.1 | 30 | 99.3 | 21.6 | 35 | 87.3 | 22.1 | 32 |
| 1200 | 92.0 | 21.1 | 34 | 82.7 | 18.7 | 32 | 98.7 | 19.9 | 32 | 102.0 | 21.4 | 37 |
| | 92.1 | 22.2 | 33 | 90.6 | 19.8 | 32 | 100.0 | 19.7 | 32 | 103.5 | 21.3 | 37 |
| | 87.5 | – | 34 | 91.0 | 24.9 | 32 | 100.5 | 22.8 | 32 | 108.0 | 22.2 | 37 |
| Avg | 90.5 | 21.6 | 34 | 88.1 | 21.1 | 32 | 99.7 | 20.8 | 32 | 104.5 | 21.6 | 37 |

1. Compressive yield strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment – 1800° F 1 hr argon atmosphere, O. Q., 1325° F 16 hr, A. C.

Table 7

Shear Strength of 3/16-In. A-286 Austenitic Alloy [3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | USS[1] 1000 psi | Hard[2] RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC |
| RT | | | | | | | 94.7 | 23 |
| | | | | | | | 94.7 | 22 |
| | | | | | | | 95.2 | 24 |
| | | | | | | | 95.3 | 24 |
| Avg | | | | | | | 96.0 | 23 |
| 600 | 79.3 | – | 77.4 | 25 | 71.0 | 26 | 83.5 | 27 |
| | 79.0 | 24 | 78.0 | 25 | 74.0 | 26 | 80.4 | 29 |
| | 82.7 | 26 | 77.0 | 27 | 72.0 | 27 | 84.8 | 30 |
| | – | – | 79.4 | 27 | – | – | – | – |
| Avg | 80.33 | 25 | 77.9 | 26 | 72.4 | 26 | 82.9 | 29 |
| 800 | 78.0 | 32 | 75.0 | 27 | 80.2 | 33 | 77.4 | 25 |
| | 78.4 | 30 | 68.0 | 23 | 78.5 | 34 | 77.4 | 28 |
| | 78.7 | 30 | 75.8 | 24 | 80.5 | 34 | 77.0 | – |
| | 77.2 | 30 | – | – | – | – | – | – |
| Avg | 78.1 | 30.5 | 72.9 | 25 | 79.7 | 34 | 77.3 | 27 |
| 1000 | 76.2 | 24 | 75.6 | 20 | 77.7 | 20 | 81.4 | 21 |
| | 76.0 | 24 | 75.6 | 19 | 76.5 | 18 | 79.8 | 21 |
| | 80.0 | 23 | 76.0 | 21 | 77.0 | 18 | 79.8 | 20 |
| | 79.6 | 23 | – | – | – | – | – | – |
| Avg | 77.9 | 23.5 | 75.7 | 20 | 77.0 | 19 | 80.3 | 21 |

Table 7 (continued)

Shear Strength of 3/16-In. A-286 Austenitic Alloy[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr / Temp °F | 1/2 USS[1] 1000 psi | 1/2 Hard[2] RC | 10 USS 1000 psi | 10 Hard RC | 100 USS 1000 psi | 100 Hard RC | 1000 USS 1000 psi | 1000 Hard RC |
|---|---|---|---|---|---|---|---|---|
| 1100 | 69.4 | 24 | 72.2 | 30 | 78.0 | 30 | 74.3 | 28 |
| | 76.0 | – | 70.2 | 32 | 78.6 | 31 | 74.5 | 29 |
| | 74.3 | 20 | 70.2 | 32 | 78.0 | 30 | 73.7 | 30 |
| | 77.7 | – | – | – | – | – | – | – |
| Avg | 74.3 | 22 | 70.8 | 31 | 78.2 | 30 | 74.1 | 30 |
| 1200 | 72.2 | 22 | 68.7 | 30 | 70.0 | 31 | 73.8 | 31 |
| | 73.5 | 28 | 69.0 | 31 | 71.6 | 33 | 69.7 | 31 |
| | 74.6 | 31 | 68.0 | 30 | 74.0 | 31 | 75.0 | 31 |
| Avg | 73.4 | 27 | 68.5 | 30 | 71.6 | 32 | 72.8 | 31 |

1. Ultimate shear strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment – 1800° F 1 hr argon atmosphere, O.Q., 1325° F 16 hr, A.C.

Table 8

Bearing Properties[4] of 0.062-In. A-286 Austenite Alloy[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] 1000 psi | UBS[2] 1000 psi | Hard[3] R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N |
| RT | | | | | | | | | | 162.2 | 217.0 | 35 |
| | | | | | | | | | | 163.5 | 214.0 | 30 |
| | | | | | | | | | | 168.0 | 237.0 | 31 |
| | | | | | | | | | | 167.5 | 237.0 | 33 |
| Avg | | | | | | | | | | 166.6 | 226.3 | 32 |
| 600 | 146.0 | 209.0 | 32 | 177.2 | 240.1 | 33 | 161.7 | 216.5 | 32 | 159.0 | 213.0 | 33 |
| | 151.0 | 213.0 | 32 | 177.2 | 238.0 | 33 | 161.5 | 216.0 | 33 | 155.5 | 212.7 | 32 |
| | 153.0 | 211.0 | 32 | 172.5 | 235.0 | 32 | 161.7 | 213.0 | 33 | 156.2 | 213.0 | 34 |
| | 153.0 | 212.0 | 31 | 177.5 | 236.5 | 32 | 161.7 | 212.0 | 33 | 164.5 | 215.0 | – |
| Avg | 150.8 | 211.0 | 32 | 176.1 | 237.4 | 33 | 161.7 | 214.4 | 33 | 158.8 | 213.4 | 33 |
| 800 | 151.5 | 206.0 | 32 | 144.0 | 206.0 | 34 | – | 203.0 | 32 | 152.0 | 204.0 | 33 |
| | 147.5 | 201.5 | 32 | 145.0 | 205.0 | 32 | 153.0 | 207.5 | 32 | 140.5 | 210.2 | 32 |
| | 148.5 | 201.5 | 32 | 144.8 | 203.0 | 33 | 151.0 | 207.5 | 33 | 150.0 | 203.5 | 31 |
| Avg | 149.2 | 203.0 | 32 | 144.6 | 205.7 | 33 | 152.0 | 206.0 | 32 | 147.5 | 205.9 | 32 |
| 1000 | — | 193.0 | 35 | 140.0 | 194.5 | 33 | 117.5 | 189.0 | 34 | 128.5 | 206.0 | 34 |
| | 136.5 | 193.0 | 33 | 149.5 | 200.5 | 34 | 123.5 | 192.0 | 34 | 158.0 | 200.0 | 35 |
| | 145.0 | 197.0 | 33 | 143.5 | 196.0 | 33 | 147.0 | 192.0 | 34 | 129.5 | 202.0 | 35 |
| | 140.7 | 194.3 | 34 | 144.3 | 197.0 | 33 | 129.0 | 191.0 | 34 | 138.7 | 202.7 | 35 |

Table 8 (continued)

Bearing Properties[4] of 0.062-In. A-286 Austenitic Alloy[5] Sheet at Different Temperatures and Holding Times

| Hold. Time Hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] 1000 psi | UBS[2] 1000 psi | Hard[3] R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N |
| 1100 | 152.0 | 182.0 | 31 | 155.6 | 179.4 | 31 | 177.0 | 205.0 | 32 | 159.0 | 185.0 | 30 |
| | 148.5 | 185.0 | 31 | 150.0 | 183.5 | 33 | 177.2 | 205.0 | 32 | 156.0 | 186.7 | 30 |
| | - | - | - | 151.8 | 184.2 | 31 | 175.0 | 202.0 | 33 | 154.8 | 185.0 | 29 |
| Avg | 150.2 | 183.5 | 31 | 152.5 | 182.4 | 32 | 176.4 | 204.0 | 32 | 156.6 | 185.5 | 30 |
| 1200 | 157.7 | - | 31 | 154.7 | 178.8 | 34 | | | | | | |
| | 151.5 | - | 30 | 154.7 | 178.8 | 34 | | | | | | |
| | - | - | - | 154.7 | 178.8 | 34 | | | | | | |
| Avg | 154.6 | - | 31 | 154.7 | 178.8 | 34 | | | | | | |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge-distance to hole-diameter ratio 1.5
5. Heat treatment - 1800° F 1 hr argon atmosphere, O.Q., 1325° F 16 hr, A. C.

Table 9

Bearing Properties[4] of 0.062-In. A-286 Austenitic Alloy[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] 1000 psi | UBS[2] 1000 psi | Hard[3] R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N |
| RT | | | | | | | | | | 181.0 | 305.0 | 33 |
| | | | | | | | | | | 197.0 | 304.0 | 35 |
| | | | | | | | | | | 193.5 | 305.0 | 35 |
| | | | | | | | | | | 198.0 | 307.0 | 34 |
| Avg | | | | | | | | | | 192.4 | 305.3 | 34 |
| 600 | 180.0 | 274.0 | 33 | 180.0 | 272.0 | 32 | 191.0 | 276.5 | 35 | – | 270.5 | 33 |
| | 179.5 | 266.4 | 32 | 175.0 | 269.0 | 31 | 185.0 | 278.5 | 33 | 185.0 | 276.0 | 33 |
| | 176.5 | 265.0 | 33 | 181.0 | 269.0 | 32 | 188.5 | 275.0 | 33 | 178.5 | 273.2 | 33 |
| | 175.0 | 263.5 | 31 | – | – | – | 187.5 | 274.0 | 33 | 174.0 | 274.0 | 34 |
| Avg | 177.7 | 267.2 | 32 | 178.7 | 270.0 | 32 | 188.0 | 276.0 | 33 | 179.2 | 273.4 | 33 |
| 800 | 185.0 | 266.0 | 36 | 187.5 | 267.0 | 32 | 176.8 | 263.0 | 32 | 205.0 | 259.0 | 34 |
| | 180.0 | 263.0 | 36 | 163.7 | 261.5 | 34 | 175.8 | 269.0 | 33 | – | 256.0 | 34 |
| | – | 266.0 | 36 | 166.5 | 266.5 | 33 | 173.5 | 263.0 | 34 | 164.0 | 263.0 | 33 |
| Avg | 182.5 | 265.0 | 36 | 172.6 | 265.0 | 33 | 175.4 | 265.0 | 33 | 184.5 | 259.0 | 34 |
| 1000 | 171.0 | 251.0 | 34 | 168.0 | 242.0 | 35 | 173.0 | 249.0 | 33 | 187.0 | 264.0 | 37 |
| | 164.0 | 249.0 | 36 | 175.5 | 252.0 | 32 | – | 249.0 | 35 | 175.0 | 264.0 | 36 |
| | 160.0 | 249.0 | 36 | 158.5 | 249.0 | – | 169.0 | 249.0 | 35 | 181.0 | 261.0 | 36 |
| Avg | 165.0 | 249.7 | 35 | 167.3 | 244.3 | 33 | 171.0 | 249.0 | 34 | 181.0 | 263.0 | 36 |

Table 9 (continued)

Bearing Properties[4] of 0.062-In. A-286 Austenitic Alloy[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp ° F | BYS[1] 1000 psi | UBS[2] 1000 psi | Hard[3] R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N |
| 1100 | 190.5 | 249.2 | 32 | 181.5 | 245.5 | 32 | 179.5 | 254.5 | 33 | 187.5 | 244.7 | 26 |
| | 190.5 | 252.0 | 32 | 186.2 | 248.0 | 32 | 191.0 | 256.0 | 33 | 189.0 | 244.7 | 26 |
| | 190.5 | 250.5 | 32 | 186.2 | 243.0 | 32 | 206.0 | 249.0 | 34 | 190.5 | 244.5 | 26 |
| Avg | 190.5 | 250.5 | 32 | 184.6 | 245.5 | 32 | 192.1 | 253.1 | 33 | 189.0 | 244.6 | 26 |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge-distance to hole-diameter ratic 2.0
5. Heat treatment –1800° F 1 hr argon atmosphere, O.Q., 1325° F 16 hr, A.C.

## 10.2 17-7 PH Stainless Steel Sheet, RH 950 Condition

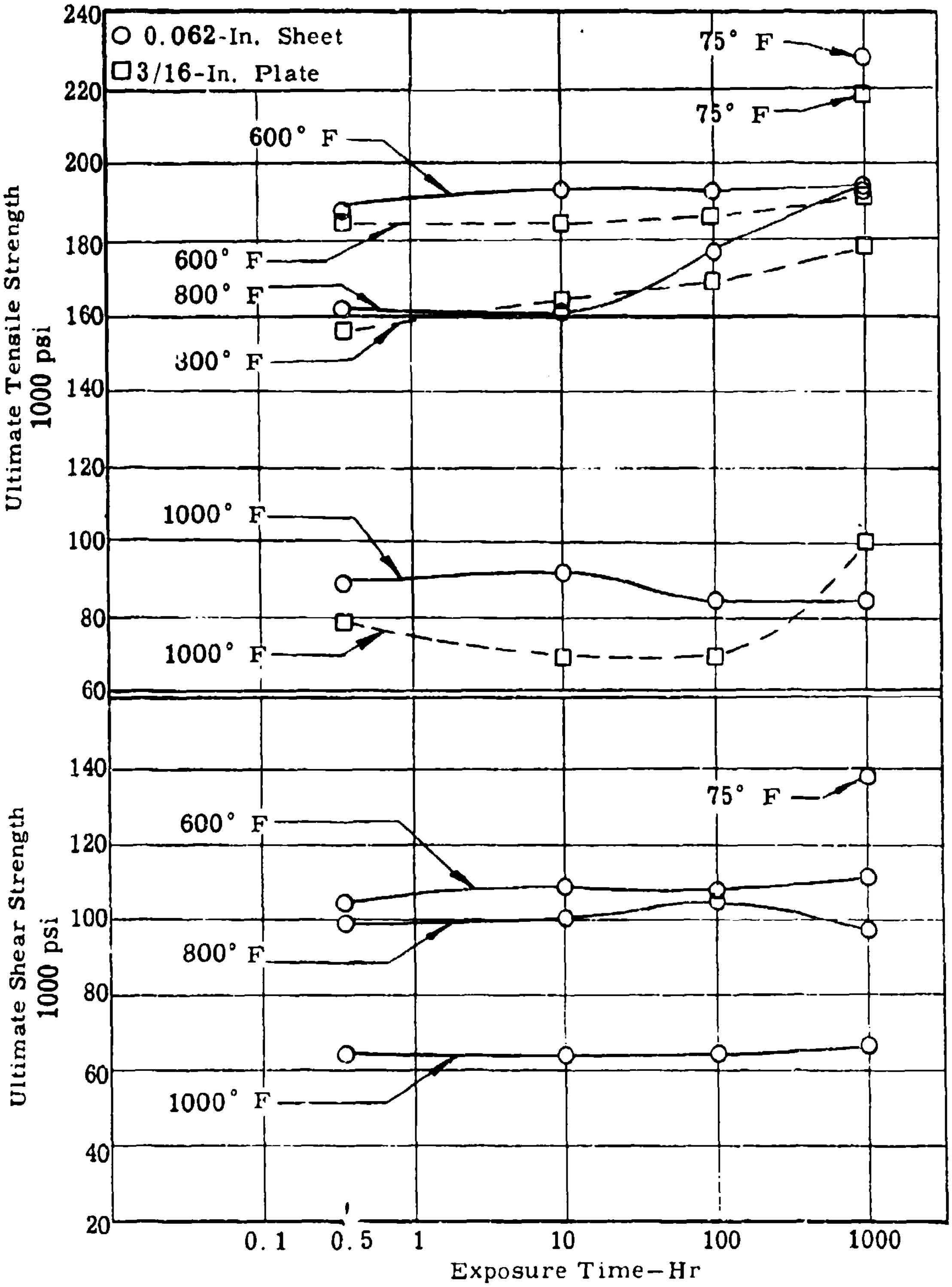


Fig. 37. Effect of exposure time on the ultimate tensile strength and ultimate shear strength of 17-7 PH stainless steel (RH 950 condition) at different temperatures.

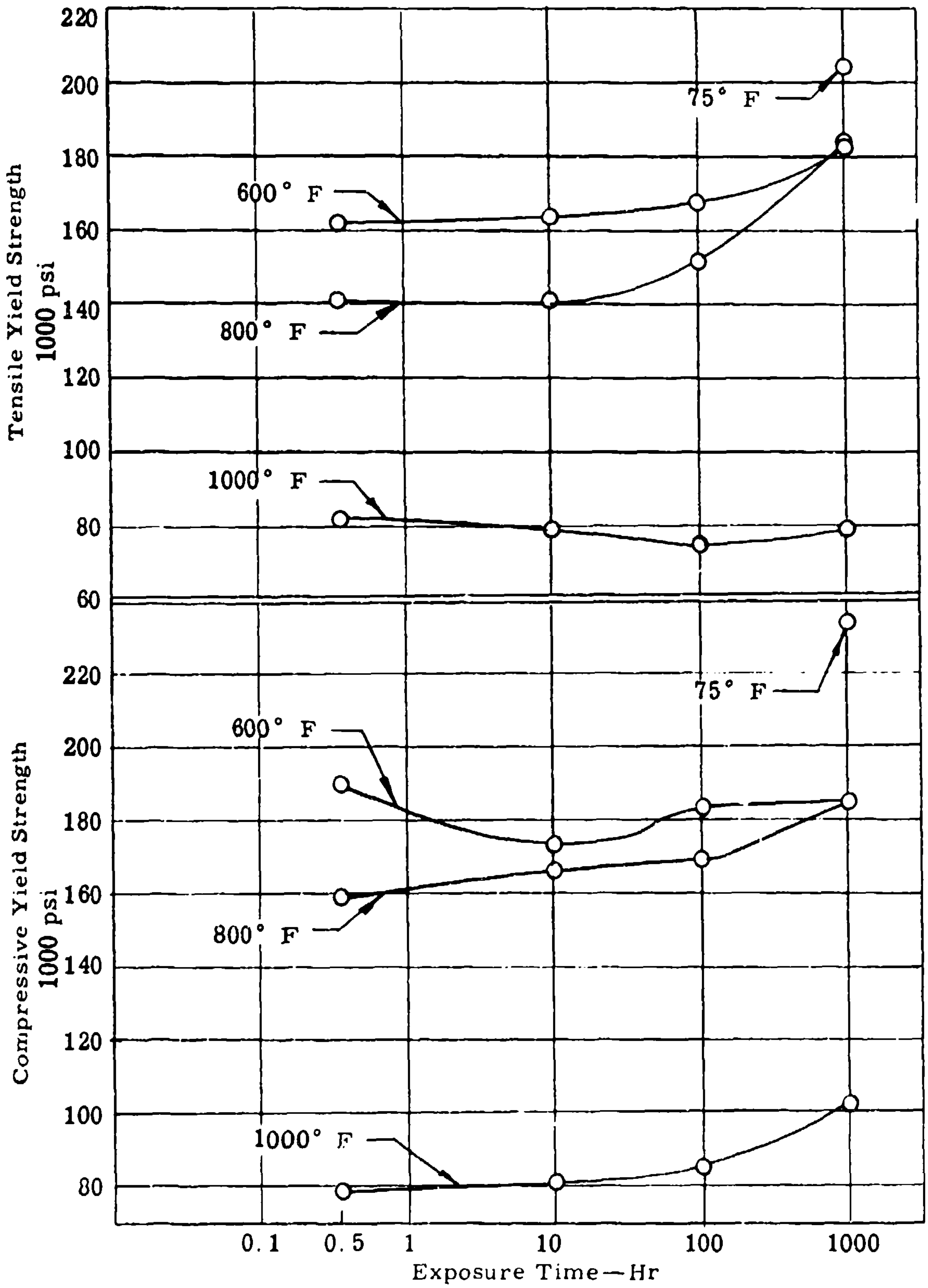


Fig. 38. Effect of exposure time on the tensile and compressive yield strength of 17-7 PH stainless steel sheet (RH 950 condition) at different temperatures.

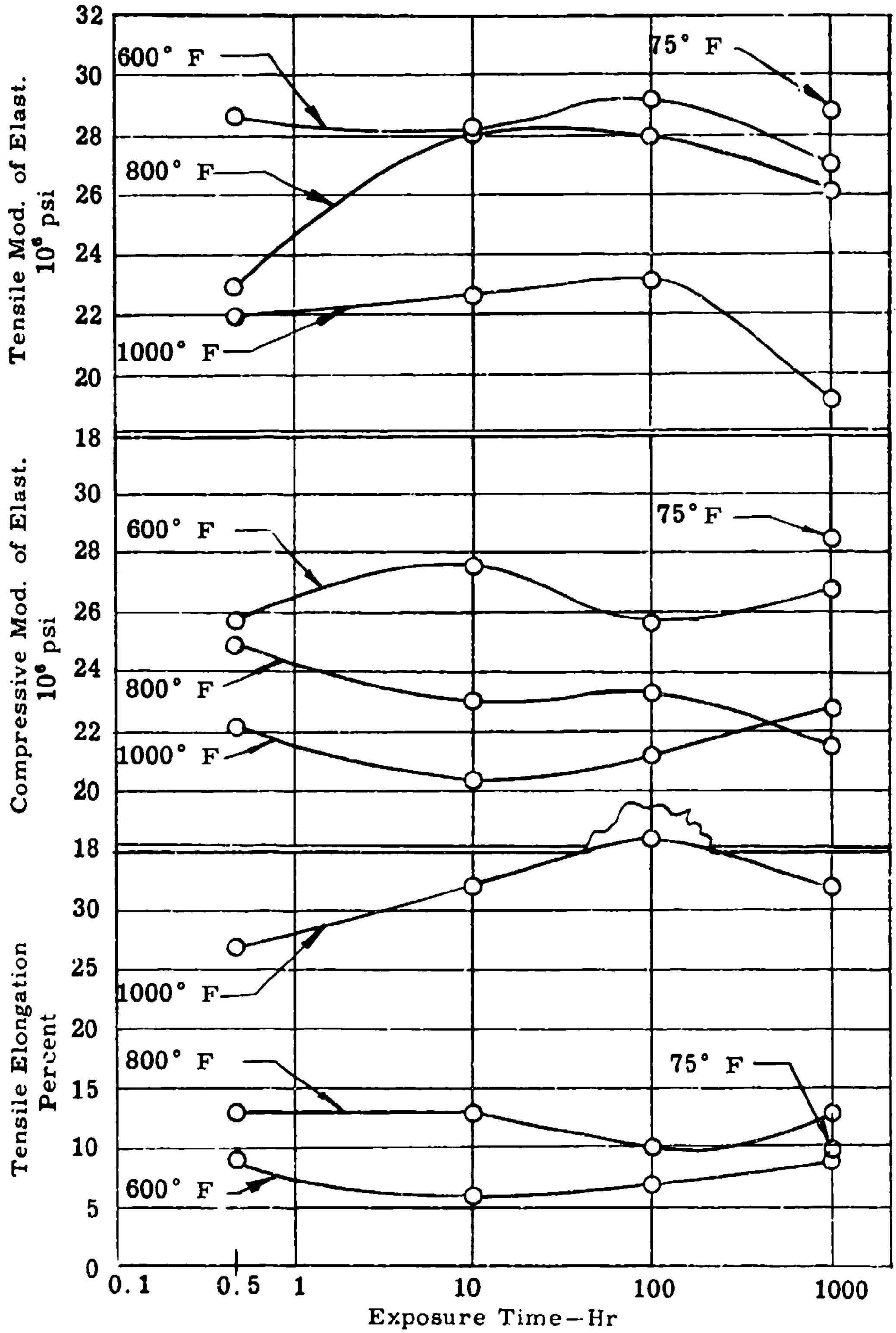


Fig. 39. Effect of exposure time on the tensile and compressive moduli of elasticity and percent elongation of 17-7 PH stainless steel sheet(RH 950 condition) at different temperatures.

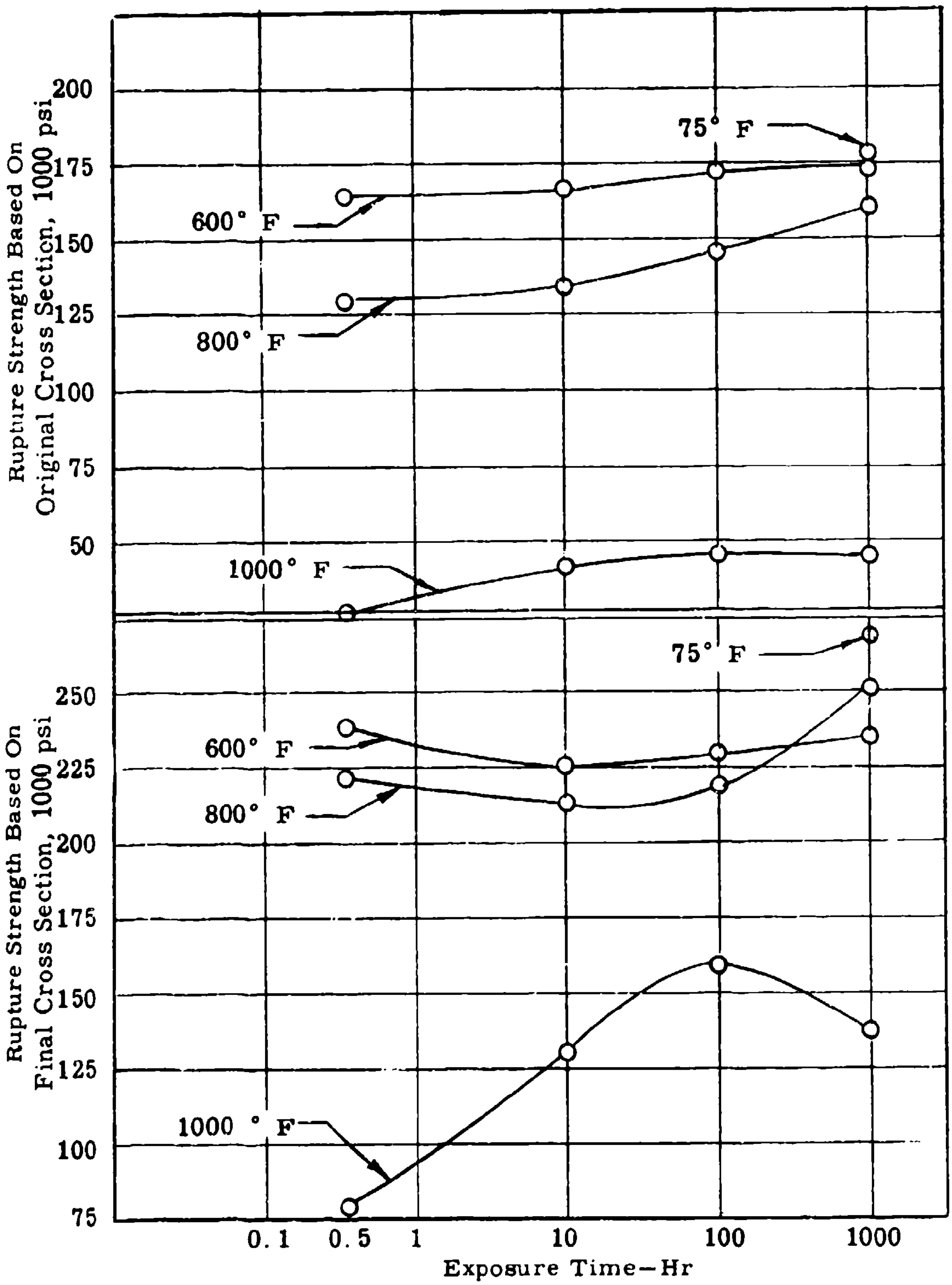


Fig. 40. Effect of exposure time on the tensile rupture strength of 17-7 PH stainless steel sheet (RH 950 condition) at different temperatures.

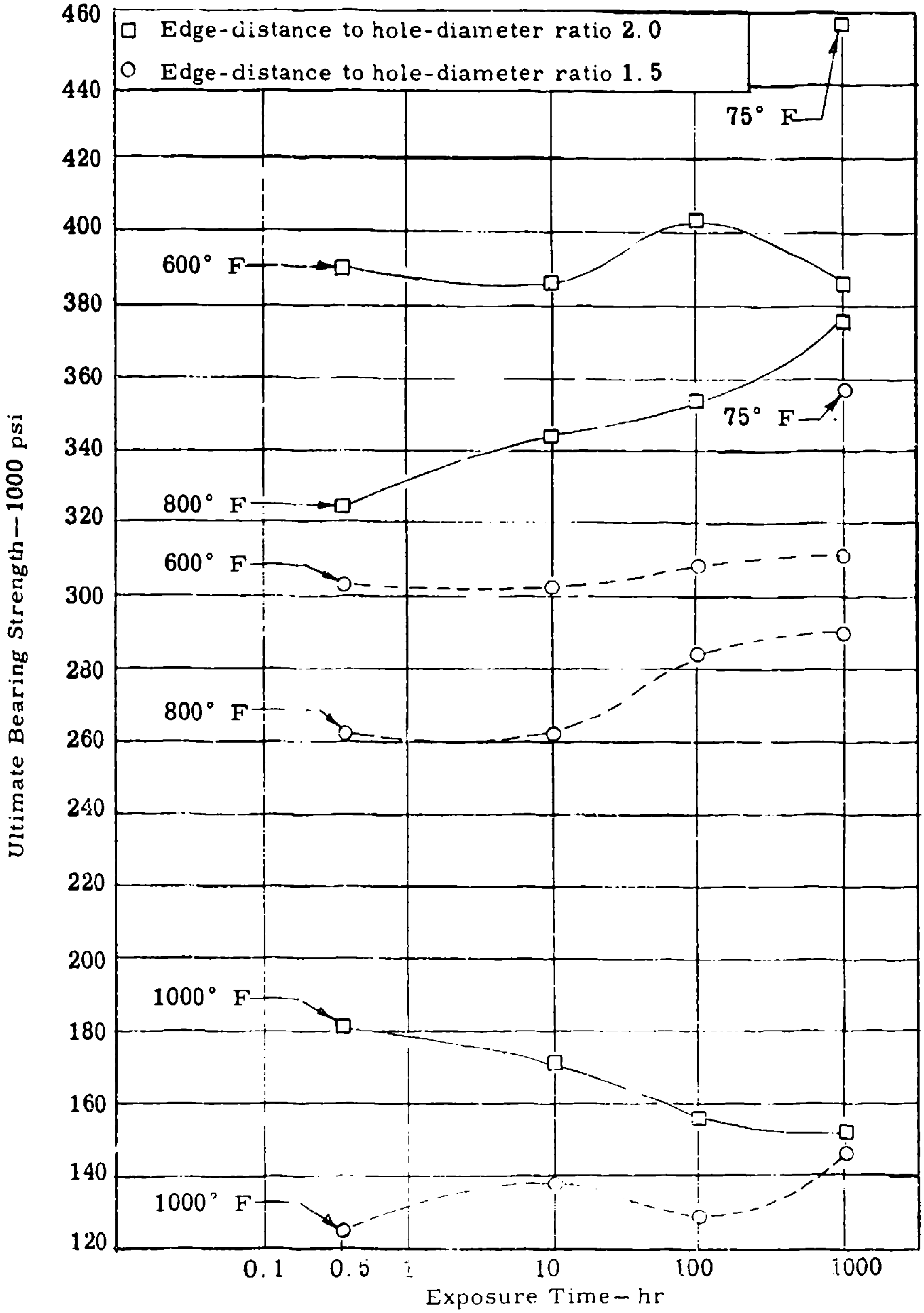


Fig. 41 Effect of exposure time on the ultimate bearing strength of 17-7 PH stainless steel sheet (RH 950 condition) at different temperatures.

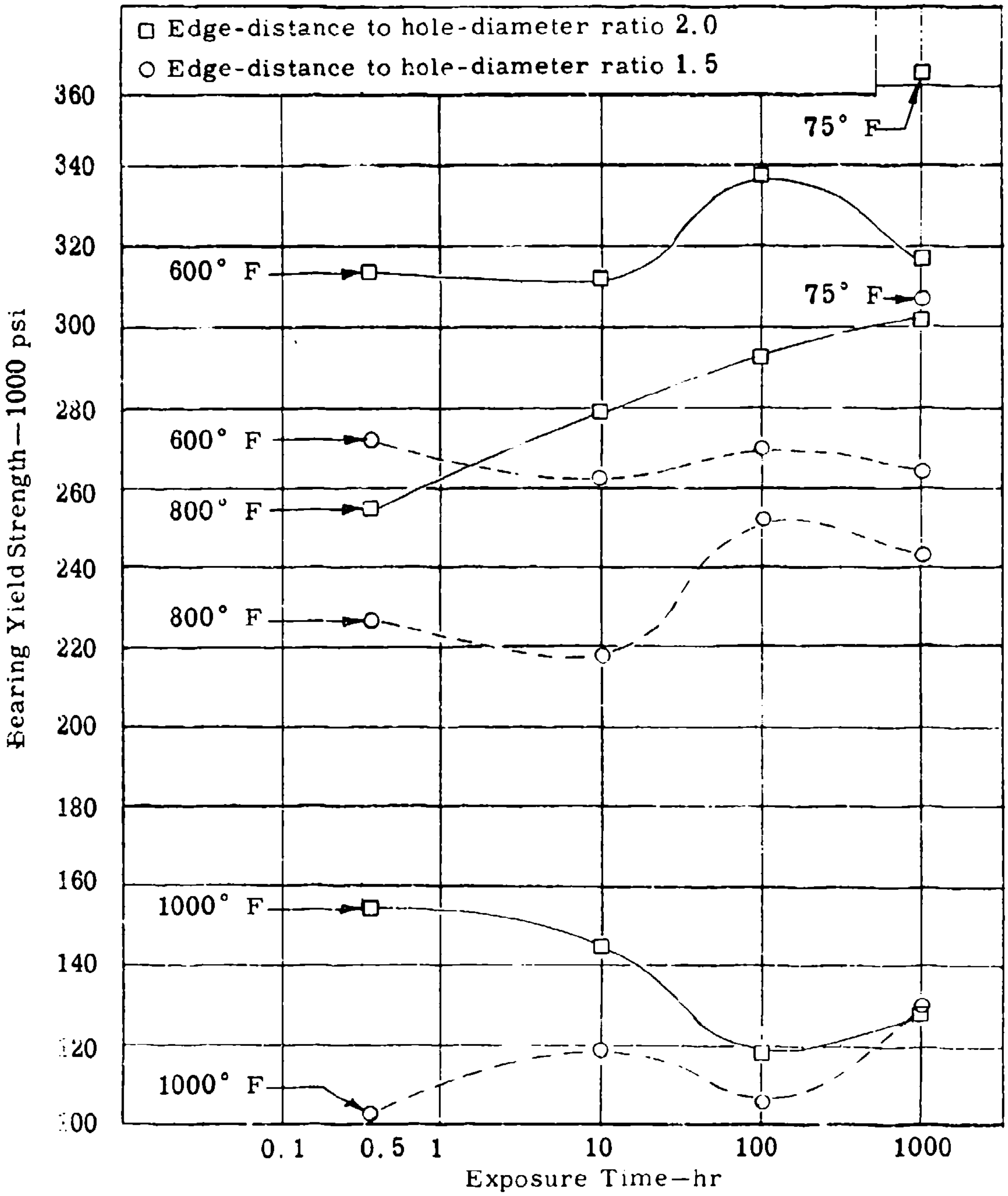


Fig. 42. Effect of exposure time on the bearing yield strength of 17-7 PH stainless steel sheet (RH 950 condition) at different temperatures.

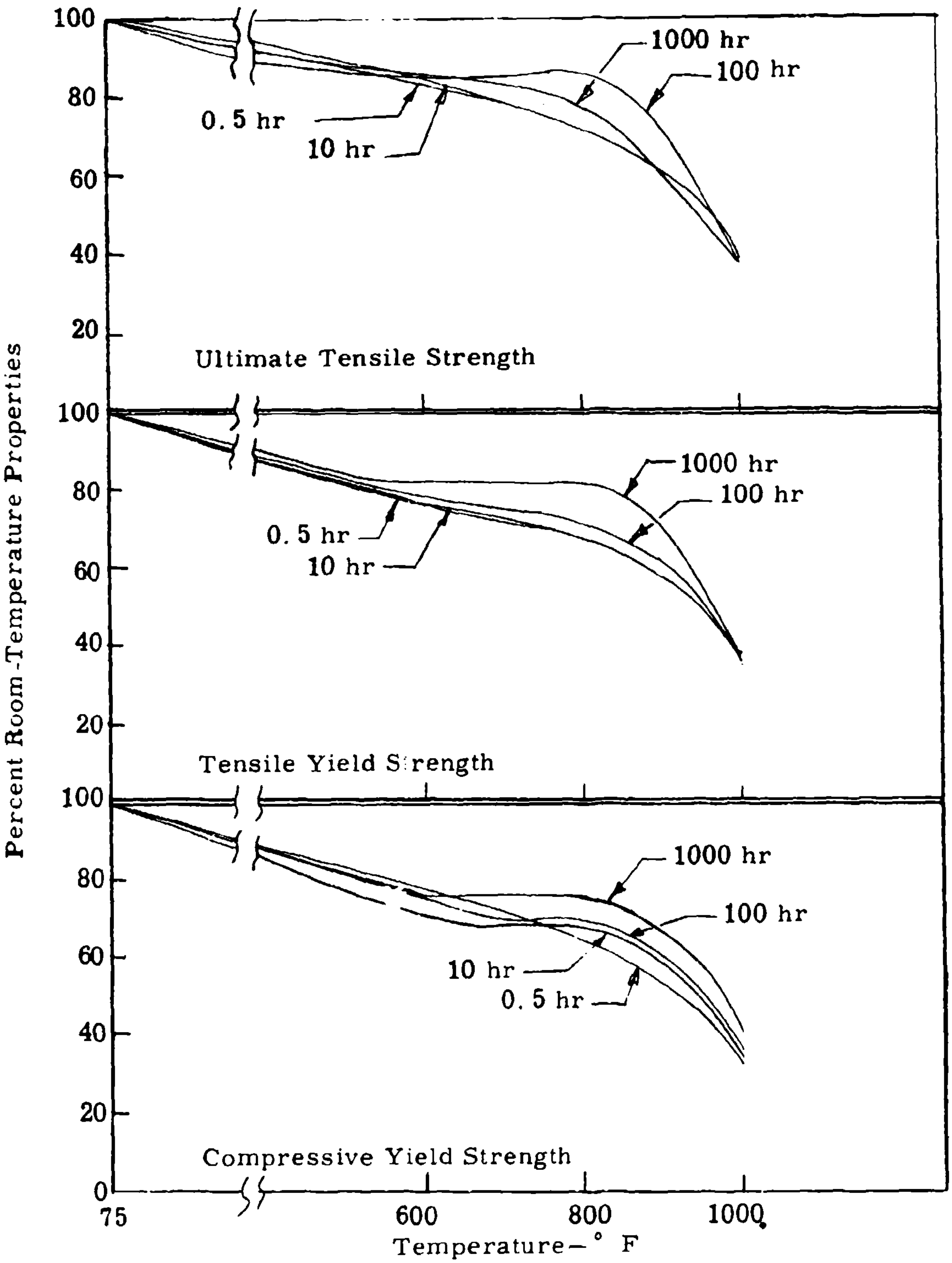


Fig. 43. Elevated-temperature strength properties as percent of room-temperature properties for 17-7 PH stainless steel sheet (RH 950 condition) at different exposure times

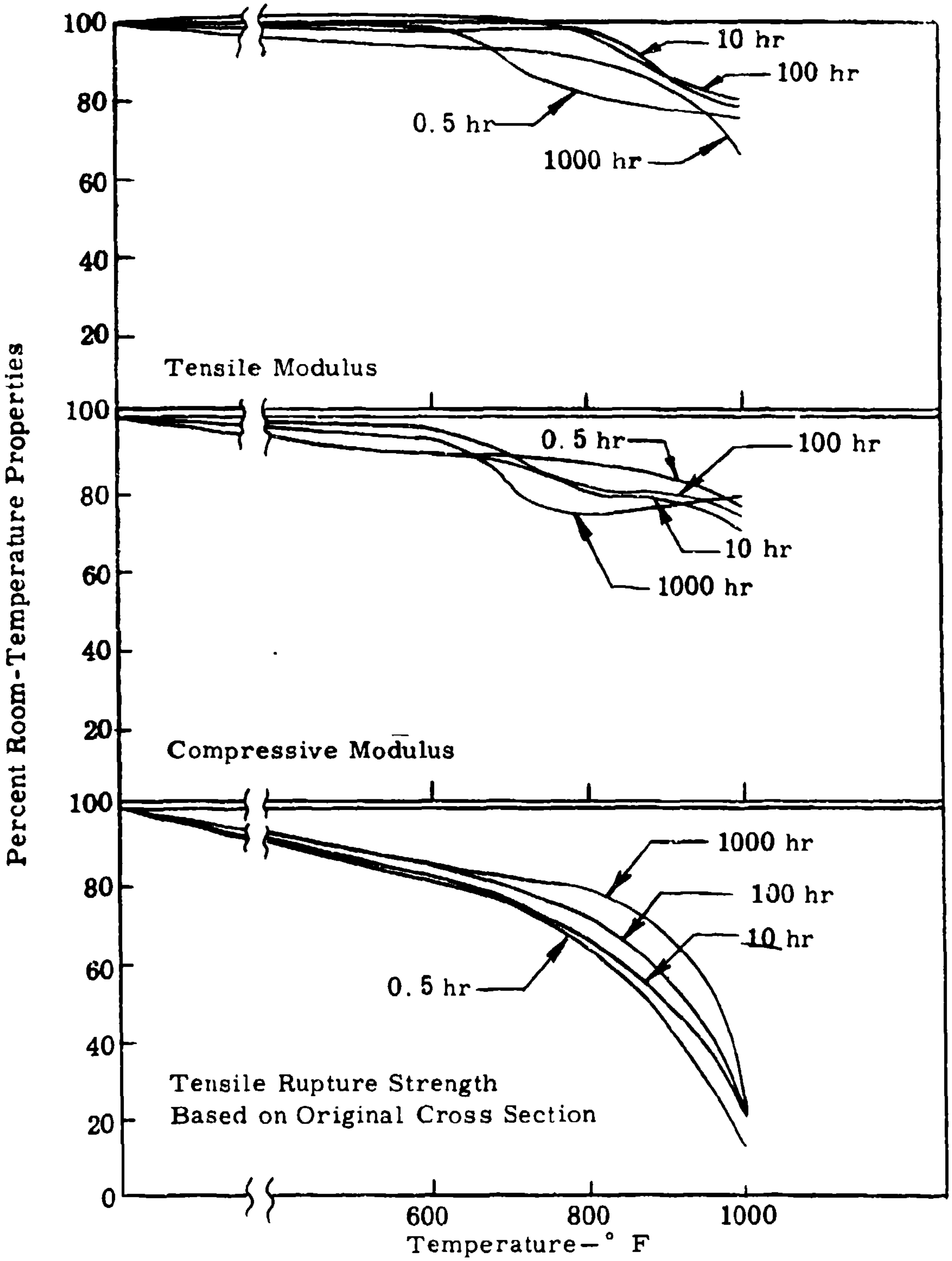


Fig. 44. Elevated temperature properties as percent of room-temperature properties for 17-7 PH stainless steel sheet (RH 950 condition) at different exposure times.

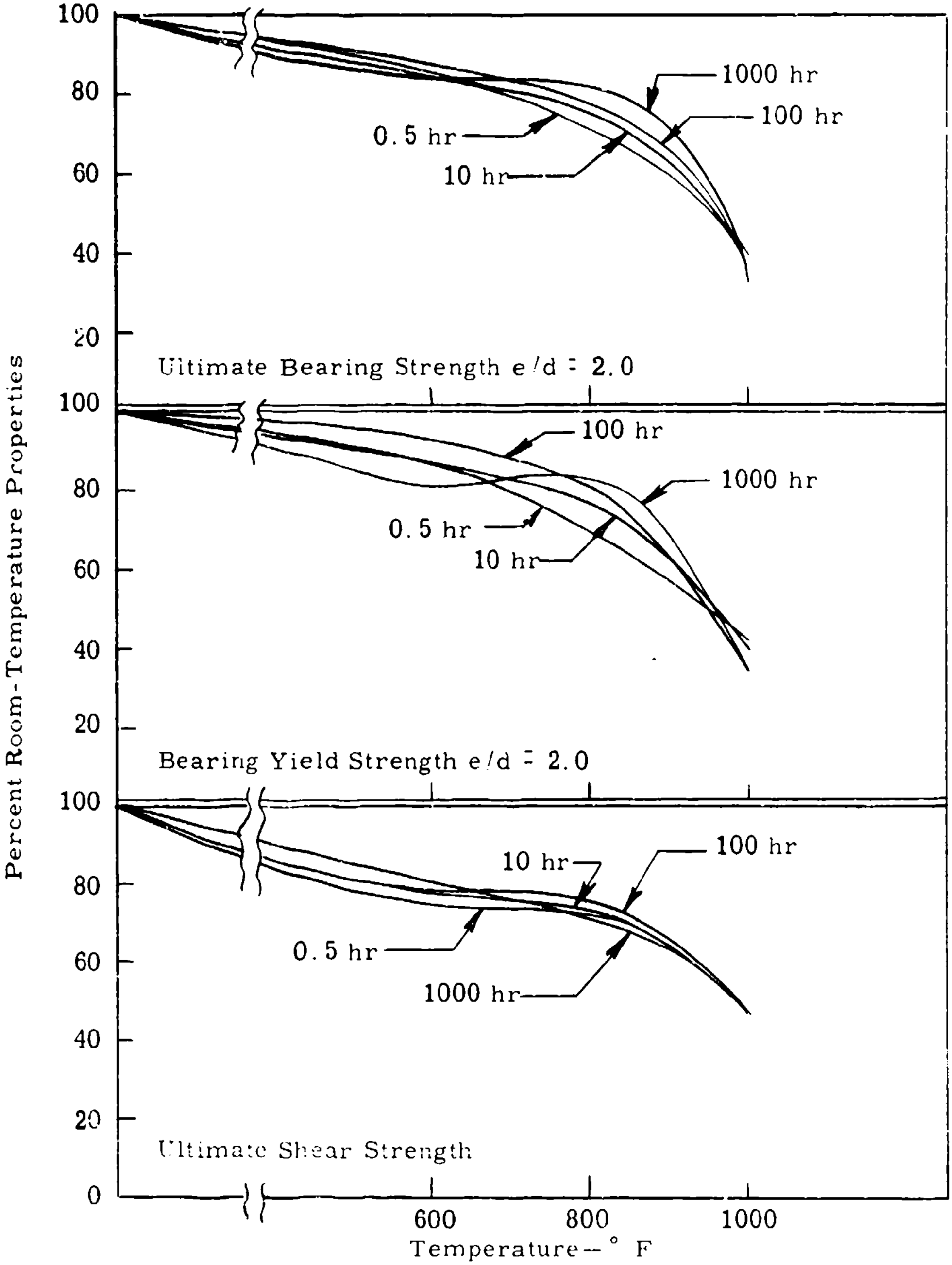


Fig. 45. Elevated-temperature strength properties as percent of room-temperature properties for 17-7 PH stainless steel sheet (RH 950 condition) at different exposure times.

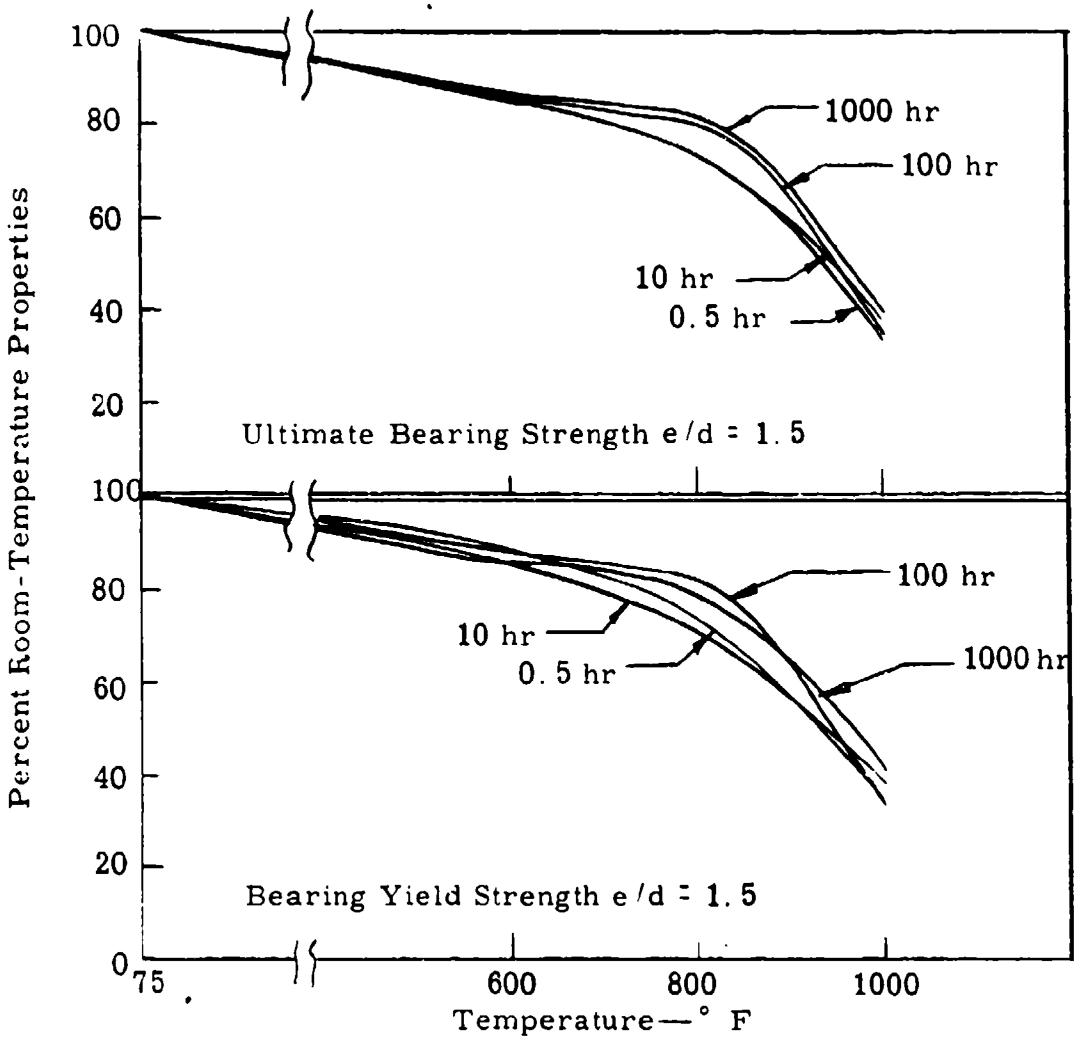


Fig. 46. Elevated-temperature strength properties as percent of room-temperature properties for 17-7 PH stainless steel sheet (RH 950 condition) at different exposure times.

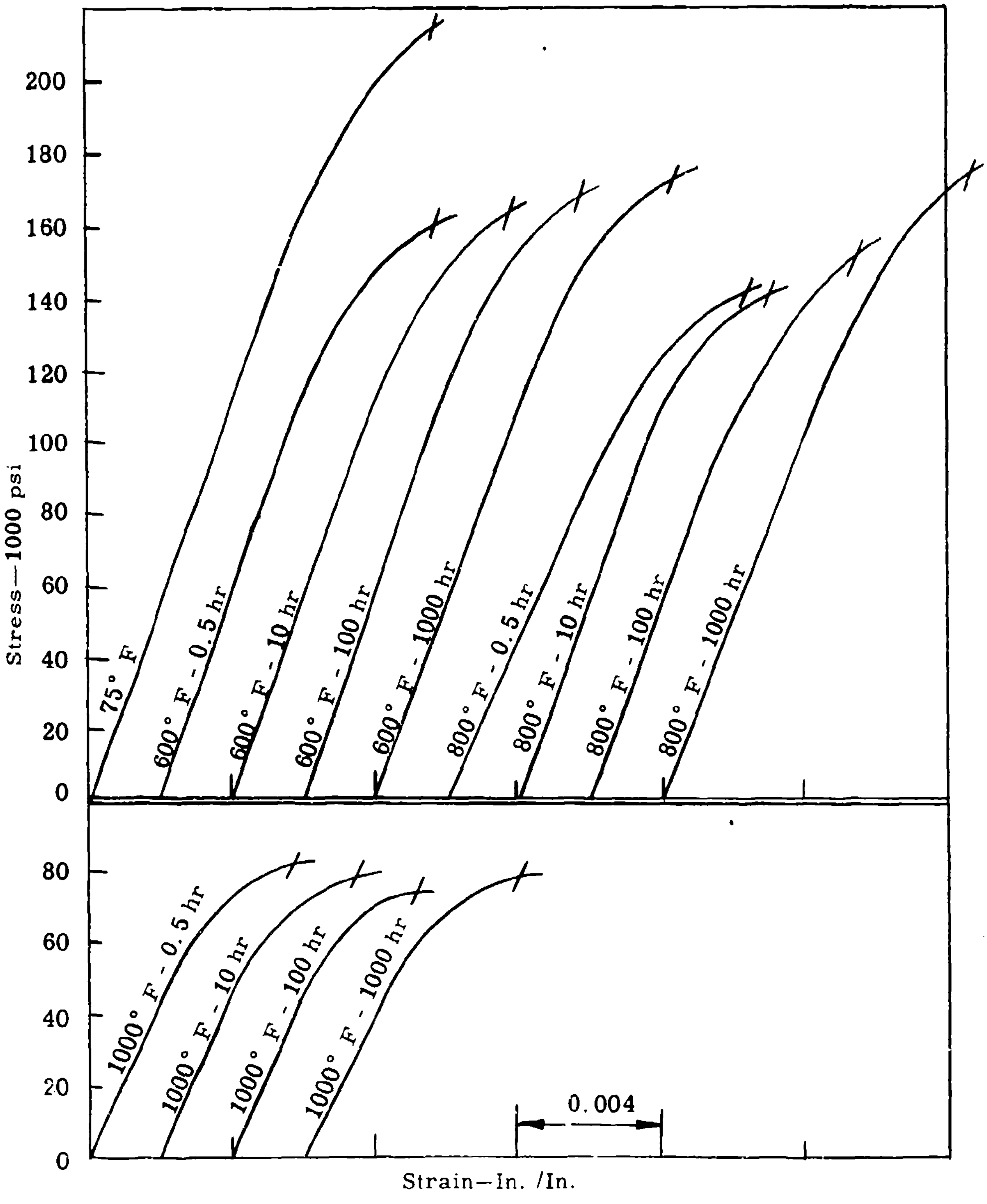


Fig. 47. Tensile stress-strain curves for 17-7 PH stainless steel sheet (RH 950 condition) at various temperatures and exposure times.

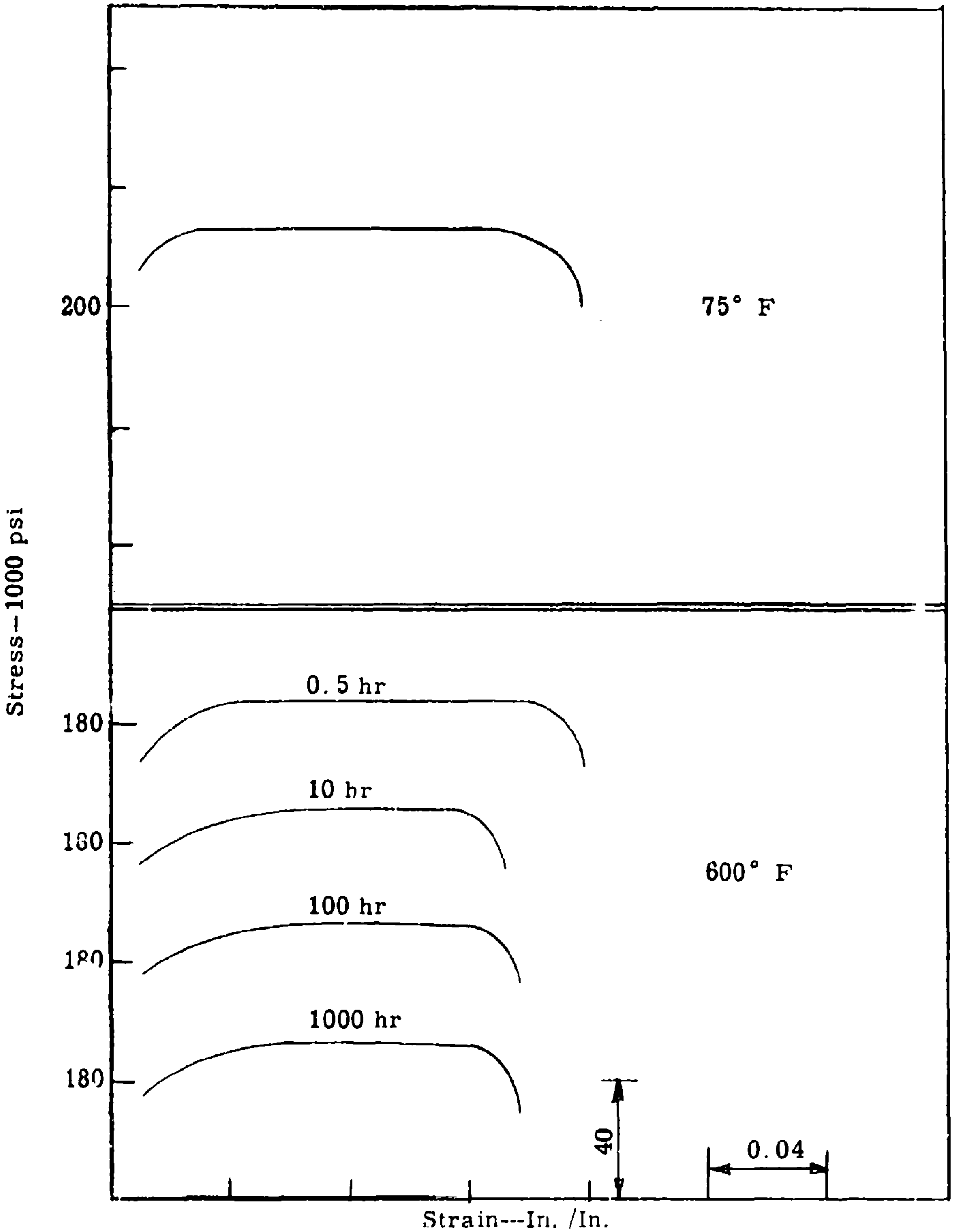


Fig. 48. Tensile postyield stress-strain curves for 17-7 PH stainless steel sheet (RH 950 condition) at various temperatures and exposure times.

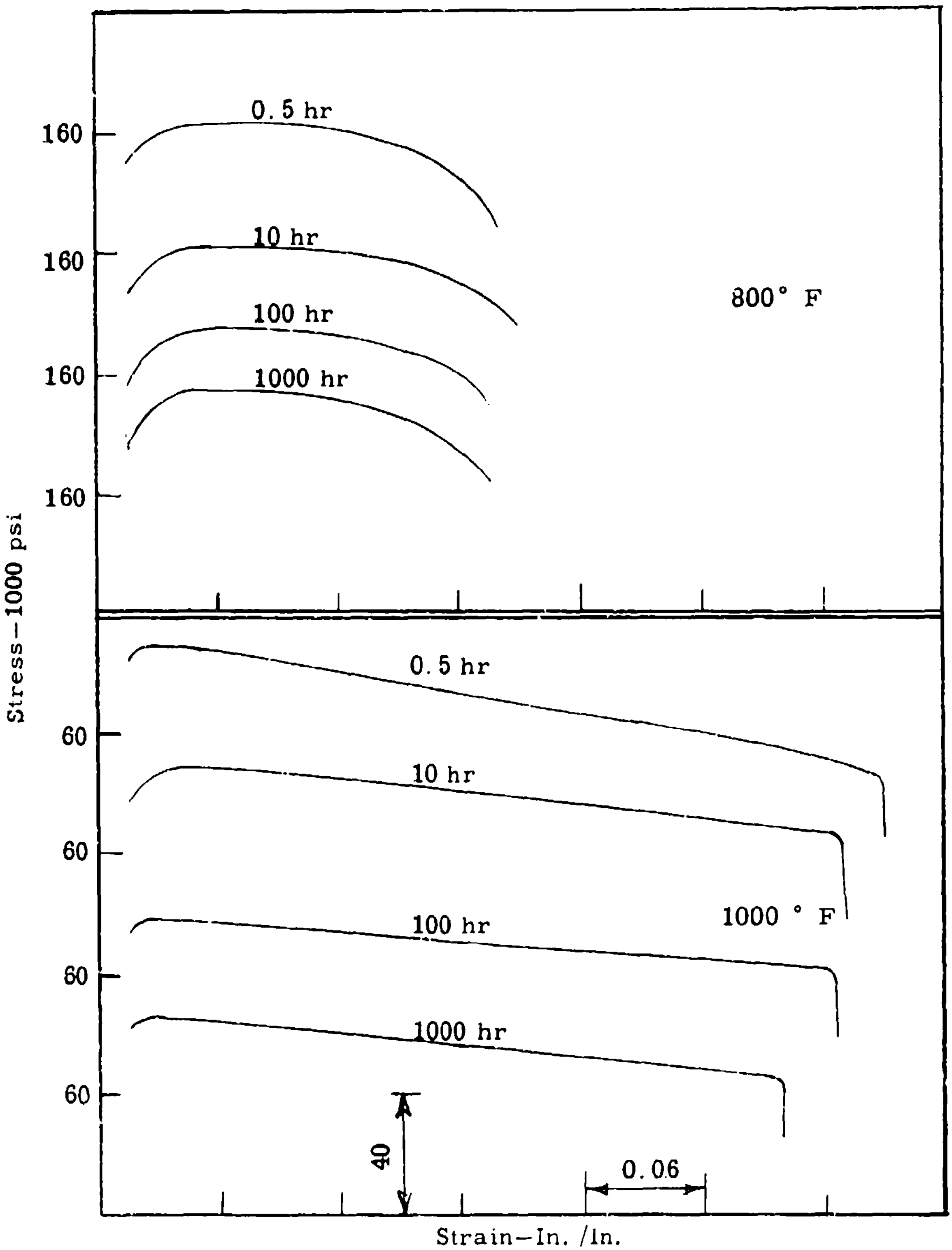


Fig. 49. Tensile postyield stress-strain curves for 17-7 PH stainless steel sheet (RH 950 condition) at various temperatures and exposure times.

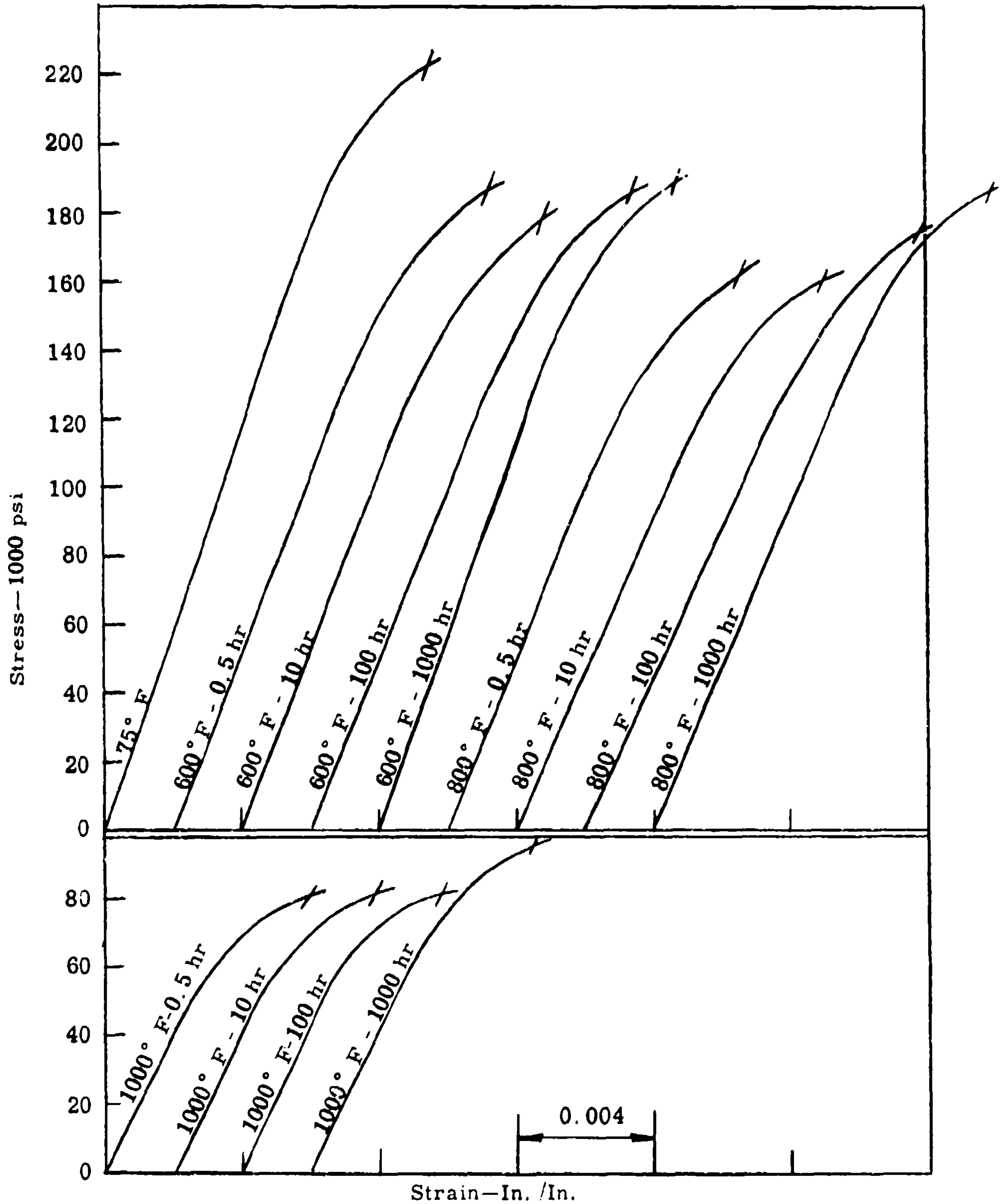


Fig. 50. Compressive stress-strain curves for 17-7 PH stainless steel sheet (RH 950 condition) at various temperatures and exposure times.

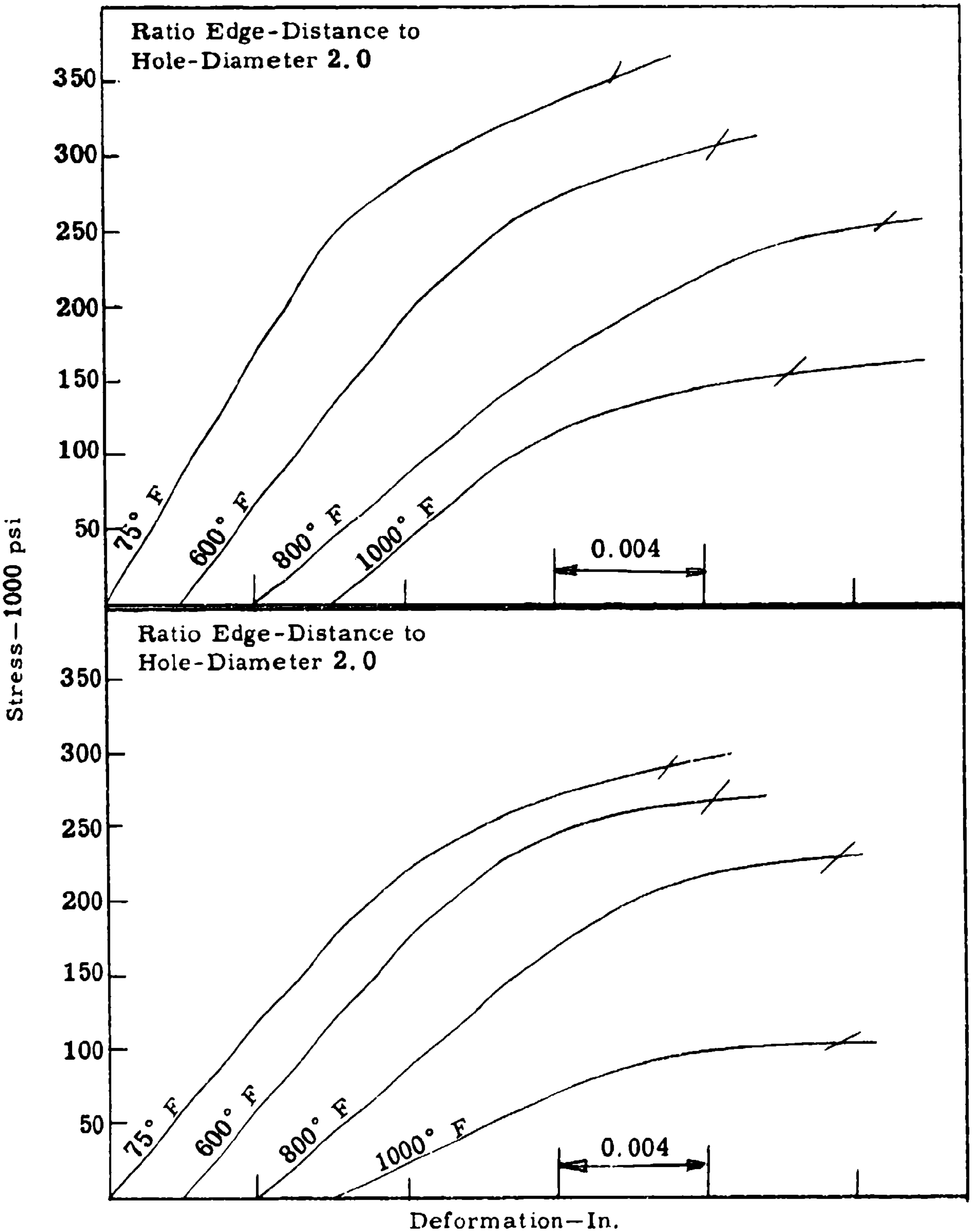


Fig. 51. Bearing stress-deformation curves for 17-7 PH stainless steel sheet (RH 950 condition) at various temperatures and one-half-hour exposure time.

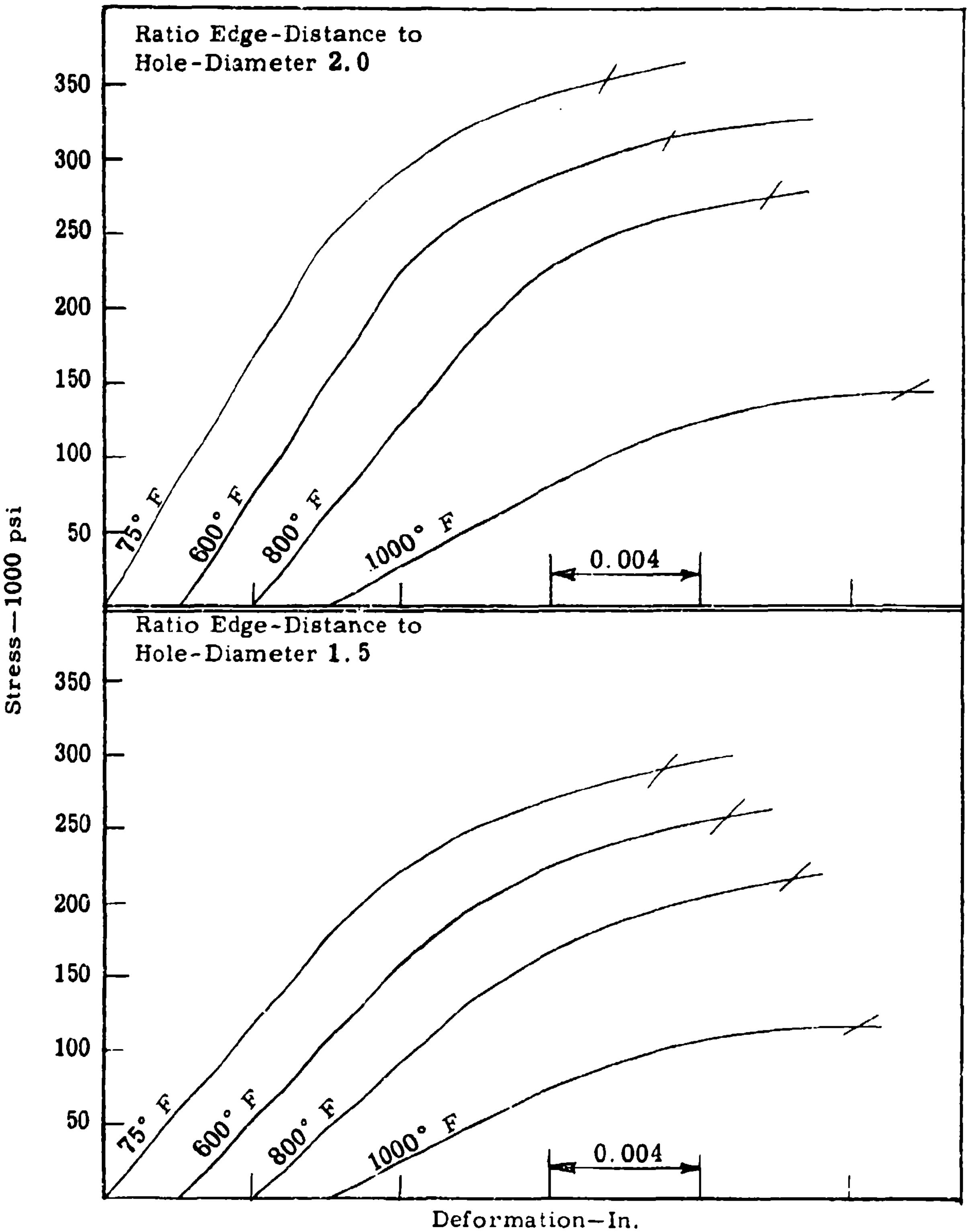


Fig. 52. Bearing stress-deformation curves for 17-7 PH stainless steel sheet (RH 950 condition) at various temperatures and ten-hour exposure time.

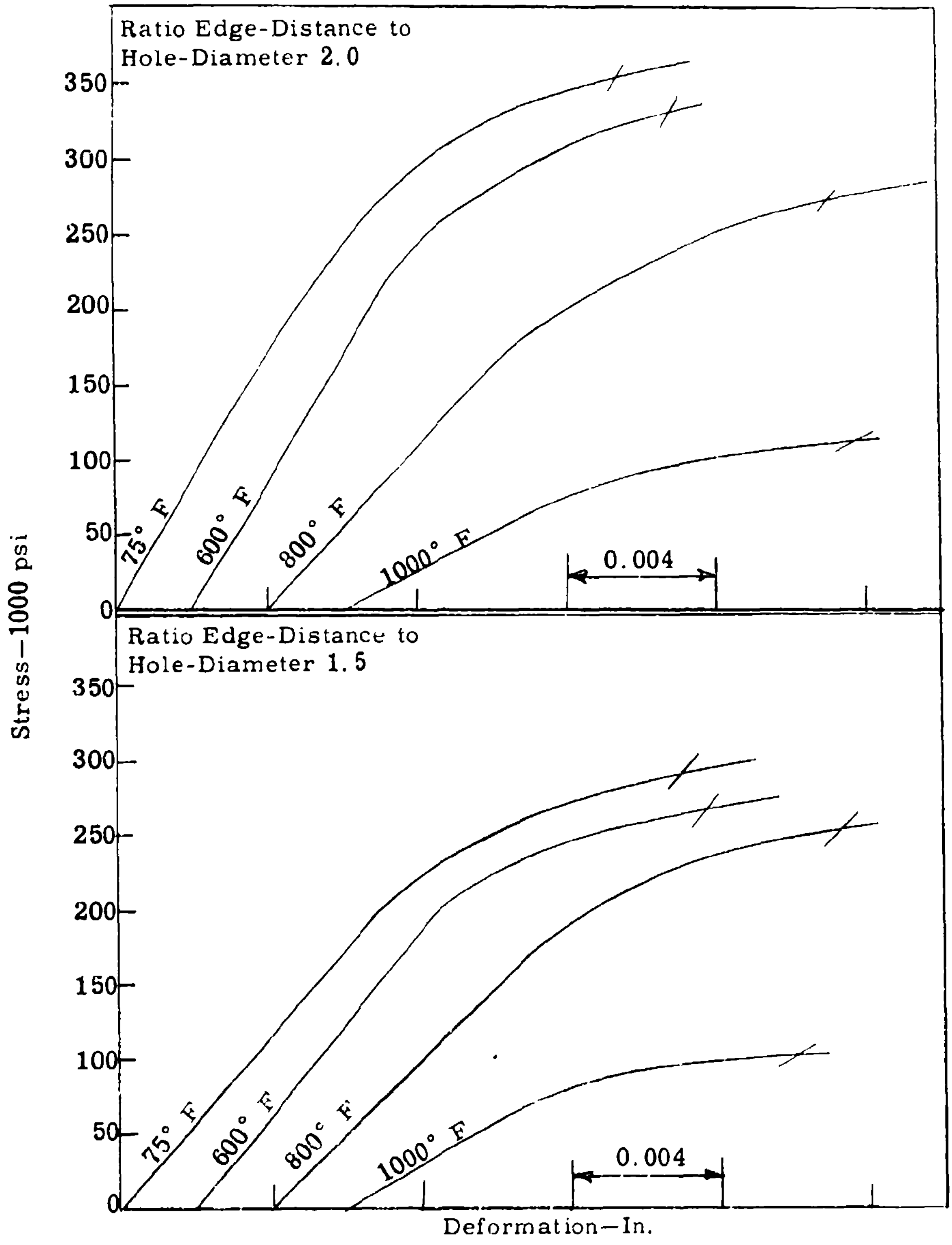


Fig. 53. Bearing stress-deformation curves for 17-7 PH stainless steel sheet (RH 950 condition) at various temperatures and one-hundred-hour exposure time.

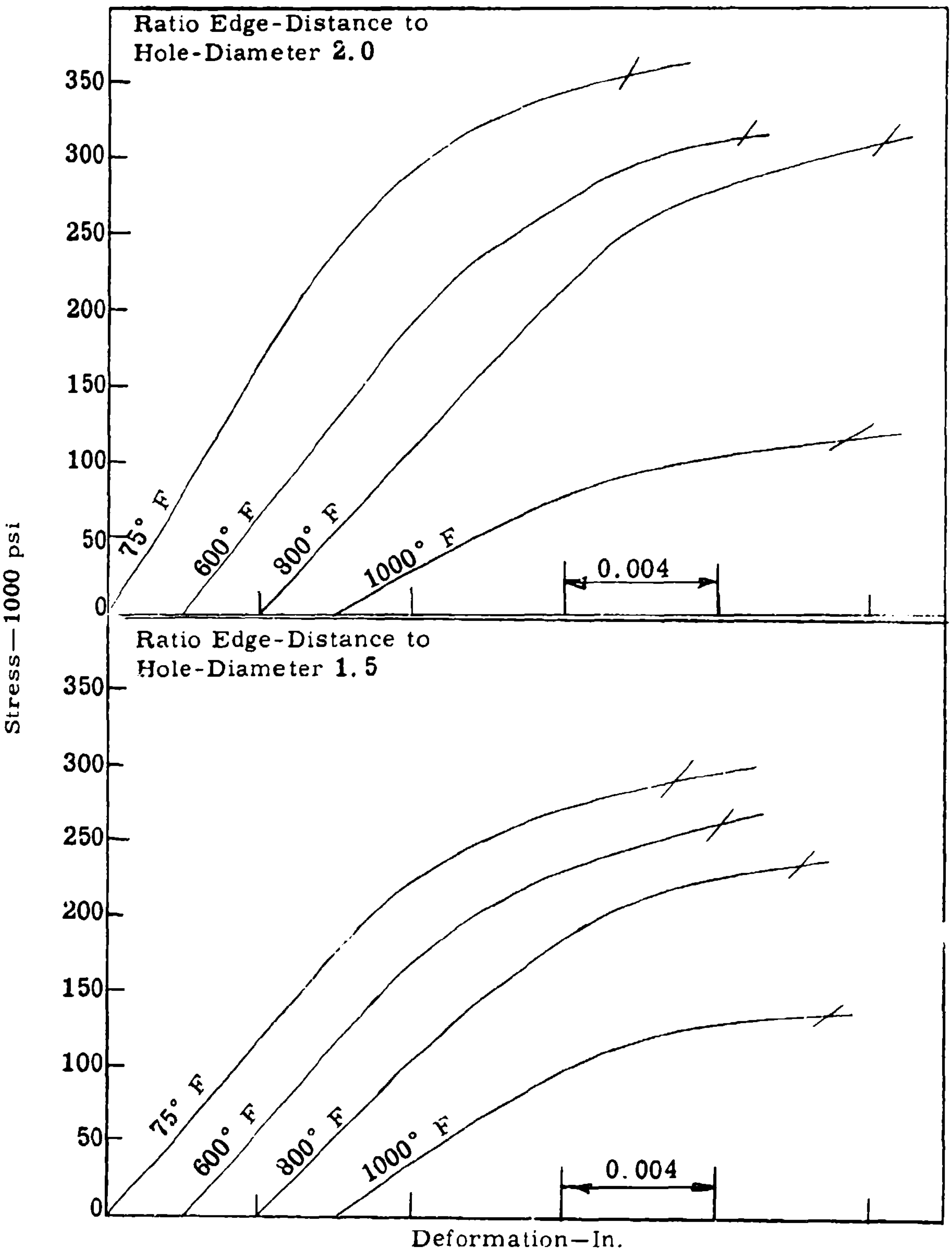


Fig. 54. Bearing stress-deformation curves for 17-7 PH stainless steel sheet (RH 950 condition) at various temperatures and one-thousand-hour exposure time.

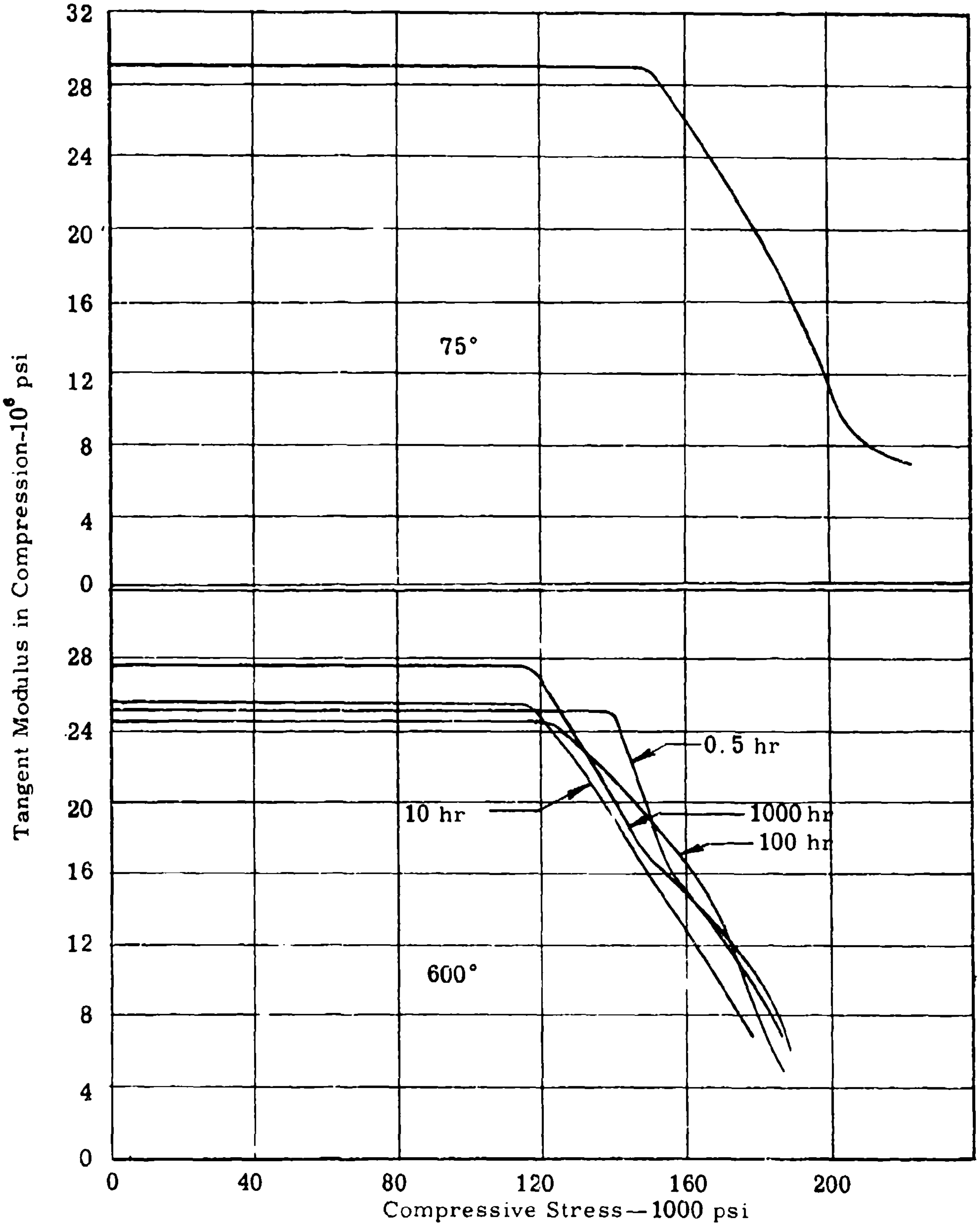


Fig. 55. Tangent-modulus vs. compressive-stress curves for 17-7 PH stainless steel sheet (RH 950 condition) at 75° F and 600° F and different exposure times.

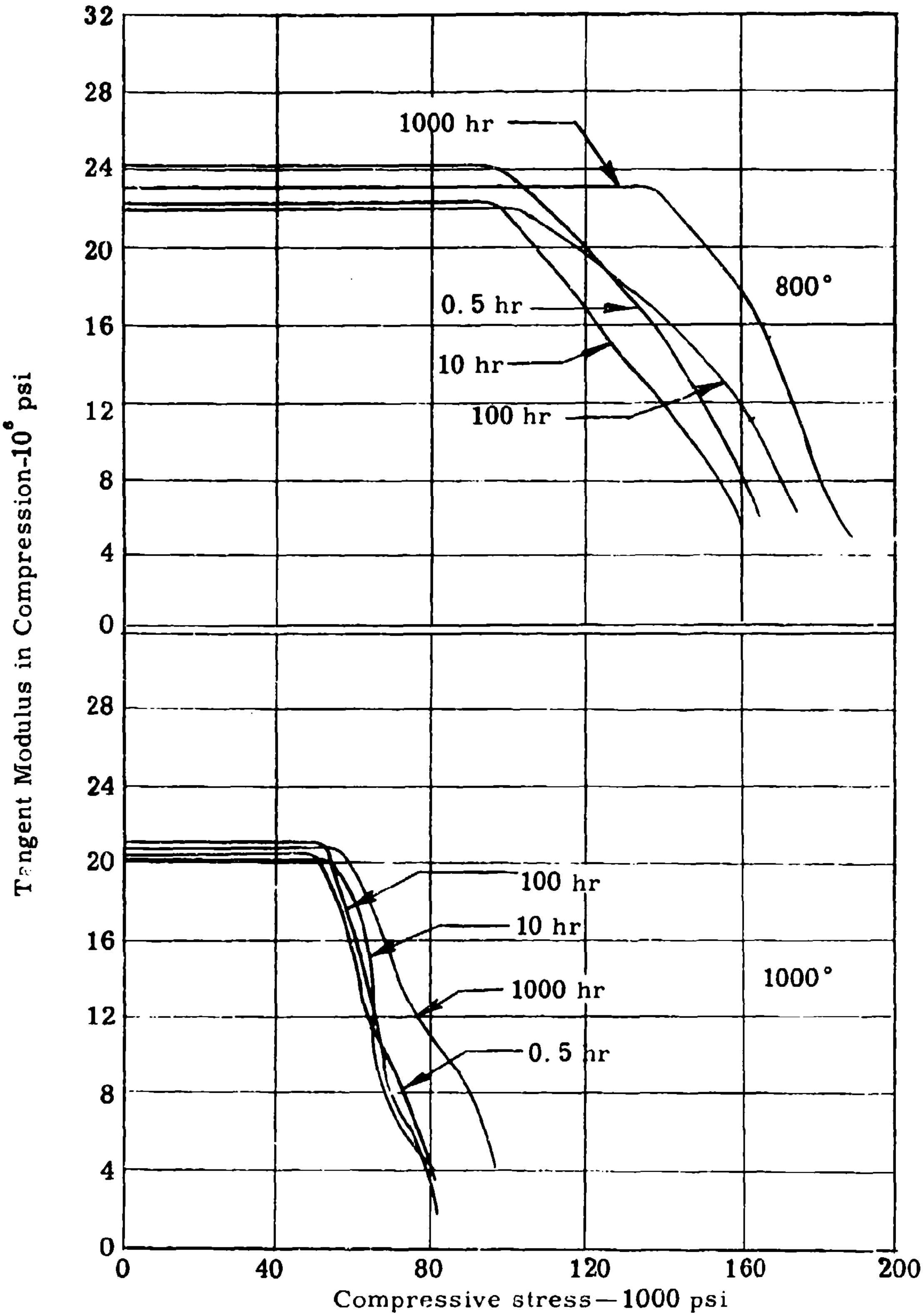


Fig. 56. Tangent-modulus vs. compressive-stress curves for 17-7 PH stainless steel sheet (RH 950 condition) at 800° F and 1000° F and different exposure times.

Table 10

Tensile Properties of 0.062-In. 17-7 PH Stainless Steel[4] Sheet at Different Temperatures and Holding Times

| Temp ° F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| RT | – | 208.0 | 226.5 | 29.3 | 10 | 53 | 200.0 | 255.0 |
| | | 215.0 | 229.0 | 28.9 | 10 | 54 | 210.0 | 285.0 |
| | | 218.5 | 229.0 | 28.3 | 11 | 52 | 200.2 | 267.0 |
| Avg | | 213.8 | 228.2 | 28.8 | 10 | 53 | 203.4 | 269.0 |
| 600 | 0.5 | 159.3 | 186.5 | 29.4 | 9 | 53 | 163.5 | 235.0 |
| | | 160.5 | 187.5 | 28.4 | 9 | 53 | 166.5 | 238.5 |
| | | 165.0 | 190.5 | 28.3 | 10 | 53 | 163.5 | 242.0 |
| Avg | | 161.6 | 188.2 | 28.7 | 9 | 53 | 164.5 | 238.5 |
| 600 | 10 | 158.0 | 192.5 | – | 5 | 53 | 162.5 | 197.5 |
| | | – | – | 27.6 | 4 | 54 | – | – |
| | | 162.8 | 195.0 | – | 8 | 53 | 164.0 | 241.0 |
| | | 172.0 | 191.5 | 29.2 | 8 | – | 172.0 | 239.0 |
| Avg | | 164.3 | 193.0 | 28.3 | 6 | 53 | 166.2 | 225.8 |
| 600 | 100 | 163.5 | 195.5 | 31.0 | 6 | 53 | 176.5 | 235.0 |
| | | 170.0 | 192.8 | 33.7 | 7 | 53 | 173.5 | 225.0 |
| | | 171.2 | 192.2 | 23.0 | 8 | 53 | 166.5 | 230.2 |
| Avg | | 168.2 | 193.5 | 29.2 | 7 | 53 | 172.2 | 230.1 |
| 600 | 1000 | 171.0 | 192.5 | 25.5 | 9 | 53 | 167.0 | 241.0 |
| | | 171.0 | 193.0 | 28.1 | 9 | 53 | 169.5 | 237.0 |
| | | 177.0 | 197.0 | 27.4 | 9 | 55 | 183.5 | 228.0 |
| Avg | | 173.0 | 194.2 | 27.0 | 9 | 54 | 173.3 | 235.3 |

Table 10(continued)

Tensile Properties of 0.062-In. 17-7 PH Stainless Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 800 | 0.5 | 141.0 | 162.5 | 22.7 | 9 | 53 | 134.0 | 201.0 |
| | | 142.0 | 159.5 | 23.2 | 16 | 52 | 128.5 | 250.0 |
| | | 140.0 | 163.0 | 24.1 | 14 | 53 | 128.5 | 217.0 |
| Avg | | 141.0 | 161.7 | 23.3 | 13 | 53 | 130.3 | 222.7 |
| 800 | 10 | 141.5 | 159.5 | 26.8 | 16 | 53 | 129.0 | 222.2 |
| | | 138.2 | 162.2 | 30.5 | 12 | 53 | 137.8 | 202.2 |
| | | 143.2 | 161.6 | 27.4 | 11 | 54 | 135.5 | 215.0 |
| Avg | | 141.0 | 161.1 | 28.2 | 13 | 53 | 134.1 | 213.1 |
| 800 | 100 | 145.8 | 175.0 | 27.9 | 9 | 54 | 150.0 | 213.0 |
| | | 155.0 | 173.2 | 29.1 | 10 | 55 | 136.5 | 234.2 |
| | | 155.5 | 182.5 | 27.0 | 11 | 54 | 152.0 | 209.0 |
| Avg | | 152.1 | 176.9 | 28.0 | 10 | 54 | 146.2 | 218.7 |
| 800 | 1000 | 174.5 | 195.0 | 27.6 | 12 | 56 | 166.6 | 266.0 |
| | | 173.5 | 193.3 | 25.5 | 12 | 57 | 157.5 | 252.0 |
| | | 175.5 | 195.4 | 25.2 | 16 | 58 | 160.6 | 237.0 |
| Avg | | 174.5 | 194.6 | 26.1 | 13 | 57 | 161.6 | 251.7 |
| 1000 | 0.5 | 79.0 | 89.6 | 22.7 | 33 | 53 | — | — |
| | | 84.5 | 88.4 | 21.2 | 22 | 53 | 27.8 | 83.5 |
| | | 83.2 | 89.5 | 22.2 | 27 | 52 | 24.7 | 74.0 |
| Avg | | 82.2 | 89.2 | 22.0 | 27 | 53 | 26.2 | 78.8 |

Table 10 (continued)

Tensile Properties of 0.062-In. 17-7 PH Stainless Steel[3] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 1000 | 10 | 72.2 | 88.8 | 19.3 | 33 | 53 | 39.1 | 119.5 |
| | | 82.5 | 93.5 | 27.6 | 33 | 54 | 42.0 | 141.0 |
| | | 81.0 | 93.0 | 21.1 | 31 | 55 | 44.4 | 132.0 |
| Avg | | 78.6 | 91.8 | 22.7 | 32 | 54 | 41.8 | 130.8 |
| 1000 | 100 | 75.2 | 88.5 | 25.6 | 31 | 54 | 55.0 | 189.0 |
| | | 75.5 | 88.0 | 21.3 | 42 | 53 | 43.8 | 141.0 |
| | | 73.7 | 78.0 | 22.7 | 35 | 49 | 39.1 | 147.4 |
| Avg | | 74.8 | 84.8 | 23.2 | 36 | 52 | 46.0 | 159.1 |
| 1000 | 1000 | 77.2 | 84.5 | 19.0 | 35 | 51 | 43.1 | 149.2 |
| | | 78.2 | 85.3 | 18.8 | 34 | 51 | 45.5 | 125.0 |
| | | 81.6 | 86.5 | 19.7 | 28 | 50 | 48.0 | 139.5 |
| Avg | | 79.0 | 85.4 | 19.2 | 32 | 51 | 45.5 | 137.9 |

1. Hardness determinations made at room temperature after tests.
2. Rupture strength based on original cross section.
3. Rupture strength based on final cross section.
4. RH 950 condition — 1750° F 10 min argon atmosphere, A. C., -100° F 8 hr, 950° F 1 hr, A. C.

Table 11

Tensile Strength of 3/16-In. 17-7 PH Stainless Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp ° F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC |
| RT | | | | | | | 215.8 | 46 |
| | | | | | | | 217.5 | 46 |
| | | | | | | | 215.5 | 46 |
| | | | | | | | 226.8 | 46 |
| Avg | | | | | | | 218.9 | 46 |
| 600 | 184.2 | 46 | 183.8 | 46 | 186.5 | 47 | 191.0 | 46 |
| | 183.5 | 46 | 185.6 | 47 | 186.2 | 47 | 191.2 | 46 |
| | 184.4 | 45 | 182.1 | 46 | 187.0 | 47 | 193.0 | 46 |
| | 184.1 | 46 | 184.0 | 47 | 186.2 | 47 | 193.0 | 46 |
| Avg | 184.1 | 46 | 183.9 | 47 | 186.5 | 47 | 192.1 | 46 |
| 800 | 149.0 | 46 | 168.0 | 48 | 167.5 | 48 | 178.7 | 50 |
| | 158.0 | 48 | 164.5 | 48 | 169.5 | 48 | 176.0 | 50 |
| | 157.8 | 47 | 165.9 | 49 | 169.5 | 49 | 179.0 | 49 |
| | 159.3 | 47 | 160.0 | 48 | 168.8 | 49 | 181.0 | 49 |
| Avg | 156.0 | 46 | 164.6 | 48 | 168.8 | 49 | 178.7 | 49 |
| 1000 | 79.92 | 45 | 71.60 | 46 | 79.20 | 46 | 103.0 | 37 |
| | 78.24 | 46 | 68.50 | 46 | 79.20 | 45 | 101.0 | 36 |
| | 77.04 | 45 | 70.70 | 46 | 80.75 | 46 | 97.20 | 34 |
| | 81.64 | 45 | — | — | — | — | — | — |
| Avg | 79.21 | 45 | 70.27 | 46 | 79.72 | 46 | 100.4 | 36 |

1. Ultimate tensile strength.
2. Hardness determinations made at room temperature after tests.
3. RH 950 Condition — 1750° F 10 min argon atmosphere, A. C., -100° F 8 hr, 950° F 1 hr, A. C.

Table 12

Compressive Properties of 0.062-In. 17-7 PH Stainless Steel[3] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | CYS[1] 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| RT | | | | | | | | | | 240.0 | 28.3 | 52 |
| | | | | | | | | | | 240.5 | 28.3 | 53 |
| | | | | | | | | | | 223.0 | 29.0 | 51 |
| Avg | | | | | | | | | | 234.5 | 28.5 | 52 |
| 600 | 193.5 | 27.2 | 52 | 182.0 | 28.1 | 52 | 182.0 | 29.0 | 53 | 187.0 | 24.2 | 52 |
| | 187.0 | 25.0 | 53 | 165.5 | 25.6 | 52 | 184.5 | 24.4 | 53 | 181.0 | 28.6 | 52 |
| | 188.5 | 25.2 | 52 | 173.0 | 29.2 | 52 | 183.5 | 23.6 | 51 | 189.0 | 27.7 | 53 |
| Avg | 189.7 | 25.8 | 52 | 173.5 | 27.6 | 52 | 183.3 | 25.7 | 52 | 185.7 | 26.8 | 52 |
| 800 | 149.7 | 28.6 | 52 | 170.0 | 21.0 | 54 | 174.5 | 21.9 | 55 | 180.2 | 19.8 | 57 |
| | 162.0 | 24.2 | 52 | 160.5 | 22.3 | 54 | 170.0 | 26.2 | 55 | 189.0 | 23.1 | 57 |
| | 165.0 | 22.2 | 54 | 169.0 | 26.0 | 54 | 163.5 | 21.7 | 54 | 186.8 | 21.6 | 58 |
| Avg | 158.9 | 25.0 | 53 | 166.5 | 23.1 | 54 | 169.3 | 23.3 | 55 | 185.3 | 21.5 | 57 |
| 1000 | 80.6 | 22.1 | 49 | 80.7 | 21.5 | 48 | 81.4 | 21.1 | 49 | 101.7 | 26.4 | 49 |
| | 80.5 | 20.5 | 49 | 81.3 | 20.3 | 49 | 77.0 | 21.1 | 49 | 109.2 | 21.2 | 48 |
| | 76.2 | 24.0 | 47 | 80.7 | 19.3 | 49 | 97.0 | 22.8 | 49 | 96.5 | 20.9 | 48 |
| Avg | 79.1 | 22.2 | 48 | 80.9 | 20.4 | 49 | 85.1 | 21.3 | 49 | 102.5 | 22.8 | 48 |

1. Compressive yield strength
2. Hardness determinations made at room temperature after tests.
3. RH 950 Condition — 1750° F 10 min argon atmosphere, A. C., -100° F 8 hr, 950° F 1 hr, A. C.

Table 13

Shear Strength of 3/16-In. 17-7 PH Stainless Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | USS[1] 1000 psi | Hard[2] RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC |
| RT | | | | | | | 140.0 | 43 |
| | | | | | | | 137.2 | 42 |
| | | | | | | | 141.0 | 42 |
| | | | | | | | 134.5 | 41 |
| Avg | | | | | | | 138.2 | 42 |
| 600 | 105.8 | – | 106.5 | 44 | 105.0 | 46 | 110.0 | 46 |
| | 101.5 | 35 | 109.9 | 44 | 109.0 | 46 | 113.0 | 47 |
| | 104.5 | – | 109.8 | 44 | 110.0 | 47 | – | – |
| | 106.5 | 43 | 108.5 | 45 | – | – | | |
| Avg | 104.6 | 39 | 108.7 | 44 | 108.0 | 46 | 111.5 | 46 |
| 800 | 98.6 | 39 | 97.1 | 40 | 108.5 | 47 | 102.5 | 48 |
| | 99.0 | 40 | 104.1 | 42 | 99.2 | 47 | 95.5 | 48 |
| | 103.8 | 38 | 101.3 | 40 | 105.5 | 46 | 94.5 | 48 |
| | 96.7 | 42 | – | – | – | – | – | – |
| Avg | 99.5 | 40 | 100.8 | 41 | 104.4 | 47 | 97.5 | 48 |
| 1000 | 67.1 | 42 | 63.0 | 40 | 63.5 | 41 | 63.0 | 39 |
| | 65.5 | 37 | 65.5 | 39 | 66.0 | 42 | 69.3 | 40 |
| | 64.1 | 34 | 63.0 | 39 | 64.0 | 41 | 69.3 | 40 |
| | 61.3 | 42 | — | — | — | — | — | — |
| Avg | 64.5 | 39 | 63.8 | 39 | 64.5 | 41 | 67.2 | 40 |

1. Ultimate shear strength.
2. Hardness determinations made at room temperature after tests.
3. RH 950 Condition — 1750° F 10 min argon atmosphere, A.C., −100° F 8 hr, 950° F 1 hr, A.C.

Table 14

Bearing Properties[4] of 0.062-In. 17-7 PH Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp ° F | BYS[1] | UBS[2] | Hard[3] | BYS | UBS | Hard | BYS | UBS | Hard | BYS | UBS | Hard |
| | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N |
| RT | | | | | | | | | | 316.0 | 358.0 | 53 |
| | | | | | | | | | | 300.0 | 355.0 | 53 |
| | | | | | | | | | | 317.0 | 361.0 | 53 |
| | | | | | | | | | | 295.0 | 352.0 | 53 |
| Avg | | | | | | | | | | 307.0 | 356.5 | 53 |
| 600 | – | 300.0 | 51 | 260.0 | 298.0 | 53 | 263.0 | 307.0 | 52 | 266.5 | 310.5 | 54 |
| | 273.0 | 307.0 | 53 | 260.0 | 302.0 | 53 | 275.0 | 309.0 | 53 | 257.0 | 311.0 | 53 |
| | 270 0 | 303.0 | 53 | 277.0 | 311.0 | 53 | 265.5 | 310.5 | 52 | 268.5 | 314.5 | 53 |
| | 273 0 | 301.0 | 52 | 253.0 | 296.5 | – | 275.0 | 307.0 | 54 | 265.0 | 305.0 | 54 |
| Avg | 272.0 | 302.8 | 52 | 262.5 | 302.0 | 53 | 269.6 | 308.4 | 52 | 264.3 | 311.3 | 53 |
| 800 | 216.0 | 255.0 | 55 | 224.5 | 264.5 | 54 | 255.0 | 286.0 | 56 | 245.5 | 290.0 | 55 |
| | 231.0 | 263.0 | 55 | 217.0 | 260.0 | 53 | 244.0 | 282.0 | 56 | 236.0 | 288.0 | 54 |
| | 234.0 | 268.0 | 55 | 212.0 | 257.0 | 53 | 257.0 | 285.0 | 56 | 248.0 | 292.0 | 54 |
| | — | — | — | 216.5 | 267.0 | 53 | — | — | — | — | — | — |
| Avg | 227.0 | 262.0 | 55 | 217.5 | 262.1 | 53 | 252.0 | 284.3 | 56 | 243.2 | 290.0 | 54 |

Table 14 (continued)

Bearing Properties[4] of 0.062-In. 17-7 PH Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] | UBS[2] | Hard[3] | BYS | UBS | Hard | BYS | UBS | Hard | BYS | UBS | Hard |
| | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N |
| 1000 | 105.0 | 135.0 | 55 | 119.5 | 140.0 | 54 | 103.0 | 129.0 | 47 | 135.5 | 149.0 | 45 |
| | 99.0 | 121.0 | 54 | 113.0 | 134.0 | 53 | 98.5 | 129.0 | 45 | 132.5 | 146.0 | 45 |
| | 105.0 | 118.0 | 55 | 123.5 | 141.0 | 53 | 117.0 | 130.0 | 47 | 122.0 | 145.0 | 43 |
| | 103.0 | 124.7 | 55 | 118.7 | 139.3 | 53 | 106.2 | 129.3 | 46 | 130.0 | 146.7 | 44 |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge-distance to hole-diameter ratio 1.5.
5. RH 950 Condition – 1750° F 10 min argon atmosphere, A.C., -100° F 8 hr, 950° F 1 hr, A.C.

Table 15

Bearing Properties[4] of 0.062-In. 17-7 PH Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] | UBS[2] | Hard[3] | BYS | UBS | Hard | BYS | UBS | Hard | BYS | UBS | Hard |
| | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N |
| RT | | | | | | | | | | 367.0 | 450.0 | 52 |
| | | | | | | | | | | 360.5 | 463.5 | 54 |
| | | | | | | | | | | 359.0 | 457.0 | 51 |
| | | | | | | | | | | 368.0 | 457.0 | 55 |
| Avg | | | | | | | | | | 363.6 | 456.8 | 53 |
| 600 | 325.0 | 397.0 | 53 | 311.0 | 387.0 | 53 | 344.0 | 397.0 | 53 | 325.0 | 387.0 | 54 |
| | 320.0 | 390.3 | 53 | 312.0 | 383.0 | — | 338.0 | 402.0 | 53 | 315.0 | 387.0 | 53 |
| | 311.0 | 390.0 | 53 | — | 386.0 | 53 | 332.0 | 405.0 | 53 | 312.0 | 382.0 | 53 |
| | 299.0 | 384.5 | 53 | 313.0 | 387.0 | 53 | 337.0 | 408.0 | 53 | 315.0 | 388.0 | 53 |
| Avg | 313.7 | 390.5 | 53 | 312.0 | 385.8 | 53 | 337.8 | 403.0 | 53 | 316.8 | 386.0 | 53 |
| 800 | 255.0 | 323.0 | 54 | 276.0 | 345.0 | 54 | 284.0 | 355.0 | 56 | 296.0 | 376.0 | 56 |
| | 262.0 | 314.5 | 53 | 272.0 | 341.0 | 54 | 296.5 | 351.0 | 55 | 299.0 | 376.0 | 56 |
| | 248.5 | 338.0 | 53 | 285.0 | 345.0 | 54 | 300.0 | 357.0 | 54 | 311.0 | 376.0 | 55 |
| | — | — | — | 283.0 | 347.0 | 55 | — | — | — | — | — | — |
| Avg | 255.2 | 325.2 | 53 | 279.0 | 344.5 | 54 | 293.5 | 354.5 | 55 | 302.0 | 376.0 | 56 |

Table 15 (continued)

Bearing Properties[4] of 0.062-In. 17-7 PH Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] | UBS[2] | Hard[3] | BYS | UBS | Hard | BYS | UBS | Hard | BYS | UBS | Hard |
| | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N |
| 1000 | 157.0 | 178.0 | 48 | 143.0 | 173.0 | 50 | 132.5 | 158.0 | 46 | 114.3 | 146.0 | 39 |
| | 149.0 | 176.0 | 52 | 146.0 | 173.0 | 52 | 113.0 | 155 0 | 48 | 118.0 | 145.0 | 40 |
| | 158.0 | 190.0 | 51 | 146.0 | 169.0 | 52 | 109.5 | 157.0 | 45 | - | 166.0 | 40 |
| Avg | 154.7 | 181.3 | 50 | 145.0 | 171.7 | 51 | 118.3 | 156.7 | 46 | 116.1 | 152.3 | 40 |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge-distance to hole-diameter ratio 2.0.
5. RH 950 condition—1750°F 10 min argon atmosphere, A. [illegible] [illegible] 8 hr, [illegible] 1 hr, A. C.

## 10.3 Thermold J Alloy Steel Sheet, Quenched and Tempered

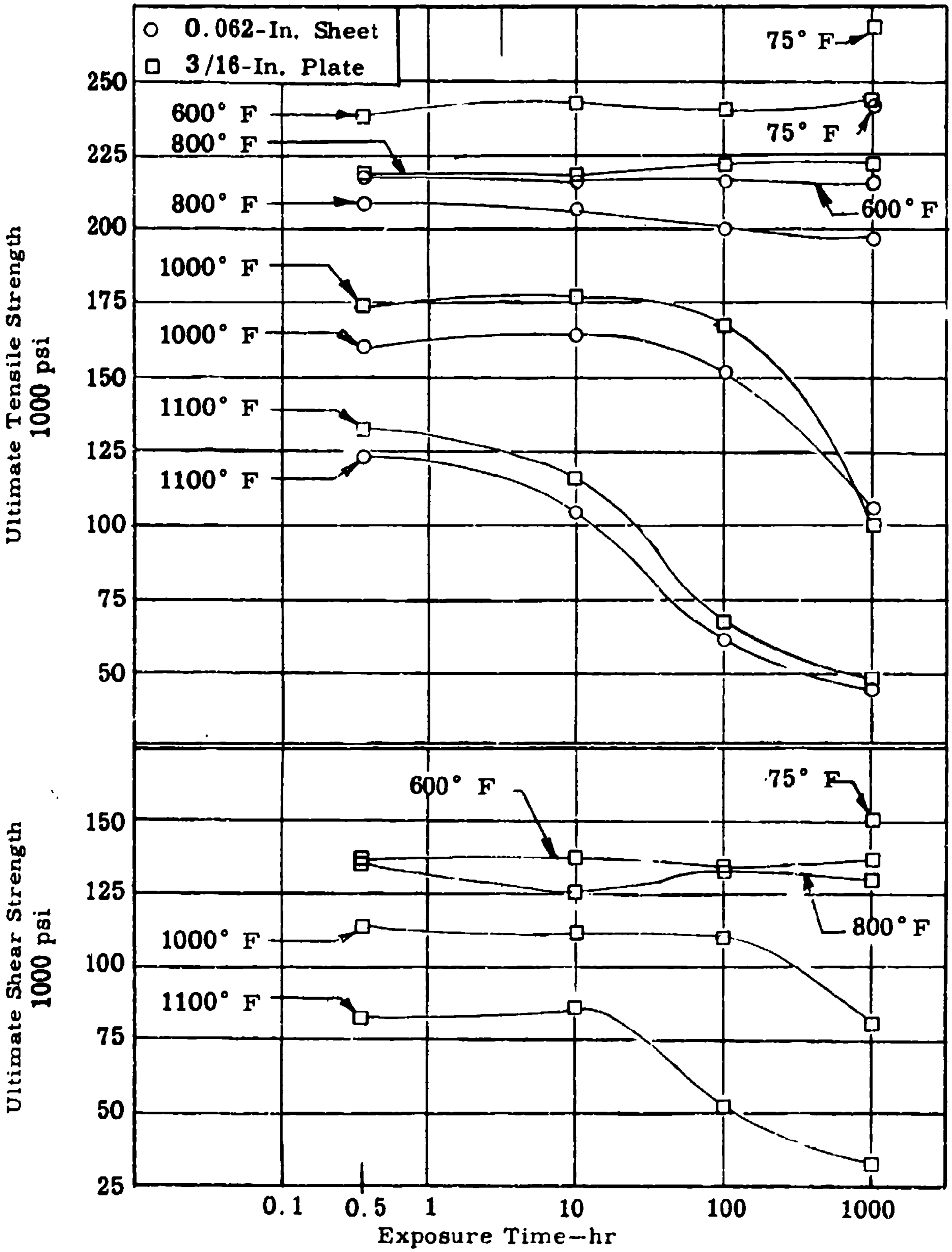


Fig. 57. Effect of exposure time on the ultimate tensile strength and ultimate shear strength of quenched and tempered Thermold J alloy steel at different temperatures.

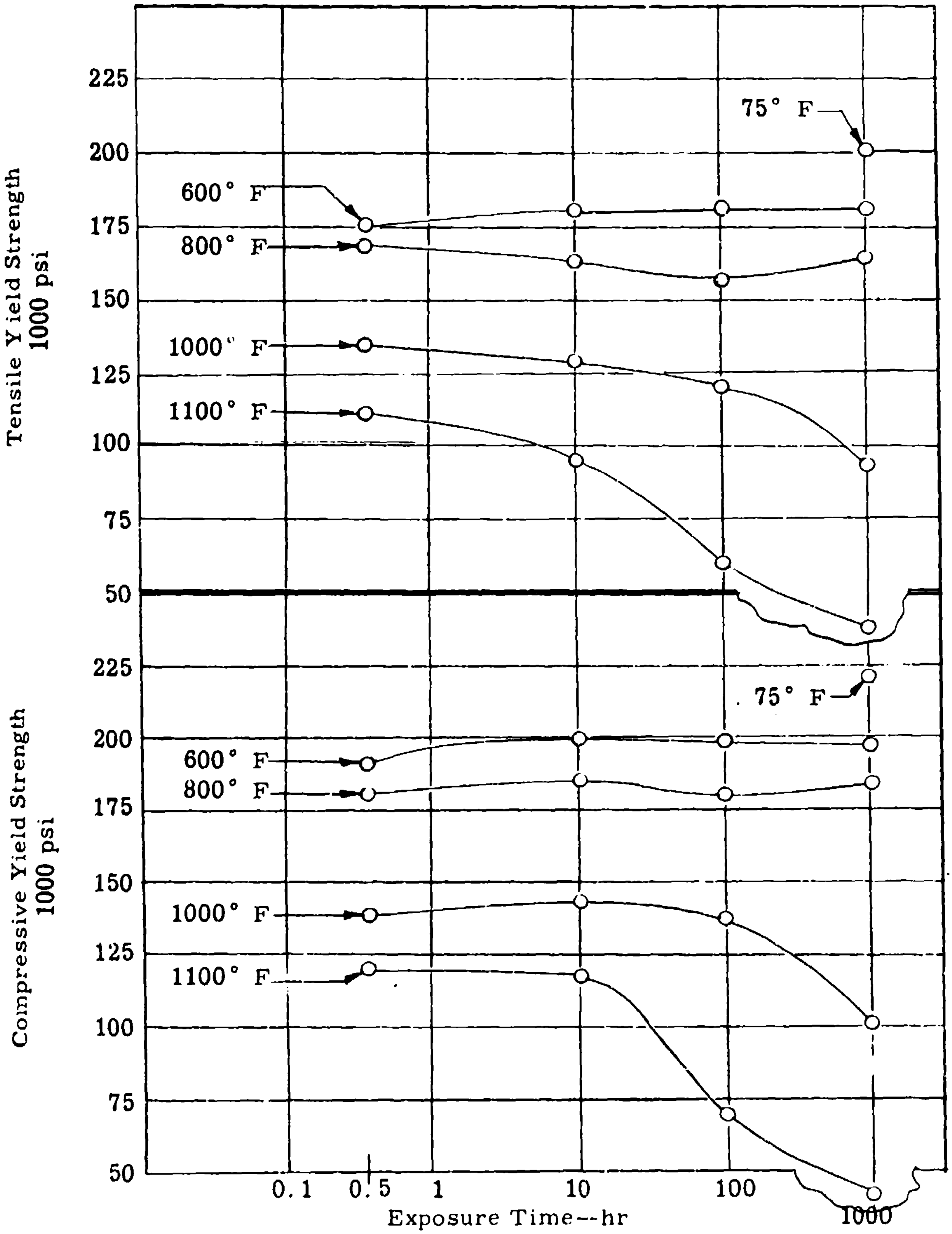


Fig. 58. Effect of exposure time on the tensile and compressive yield strength of quenched and tempered Thermold J alloy steel sheet at different temperatures.

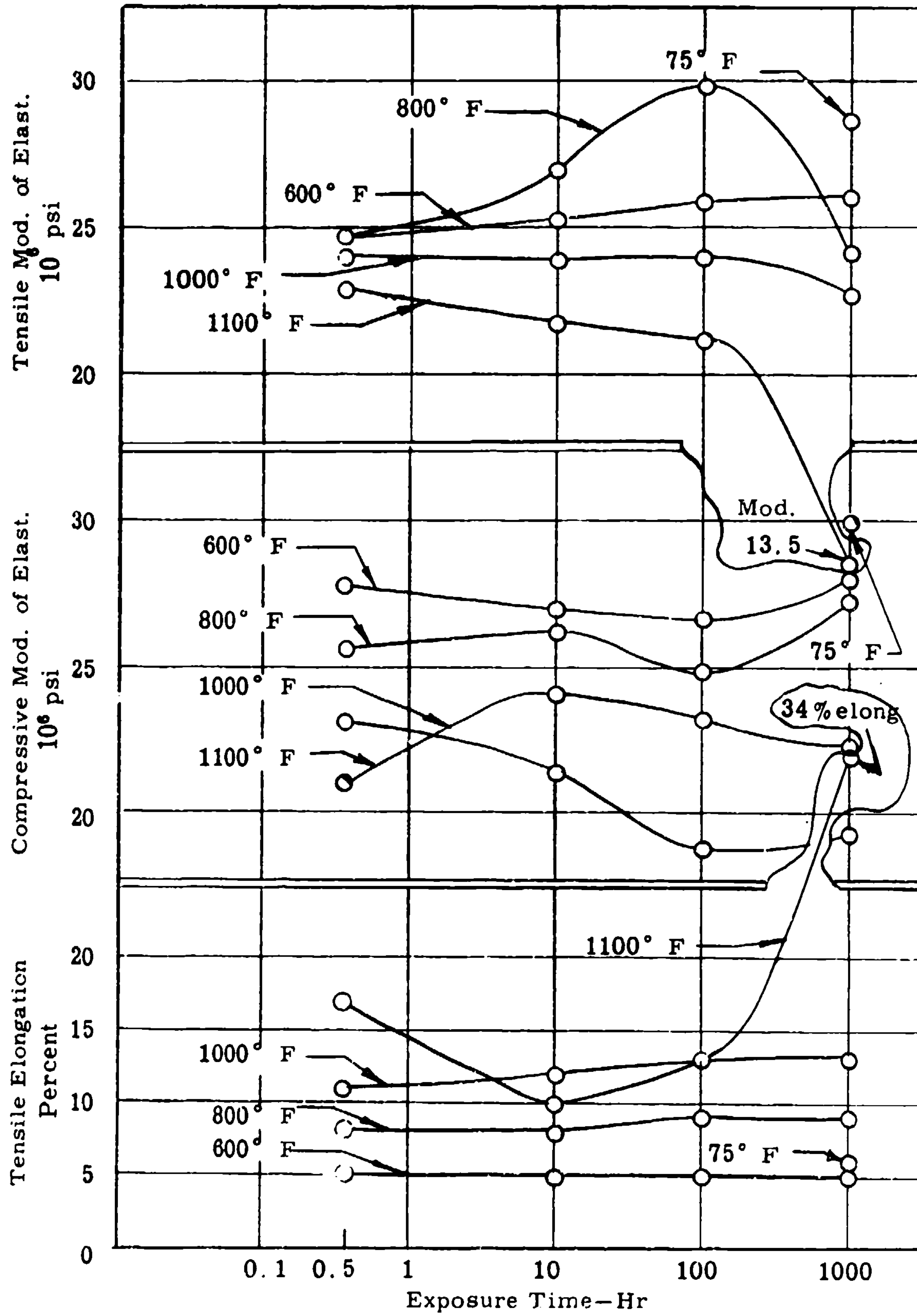


Fig. 59. Effect of exposure time on the tensile and compressive moduli of elasticity and percent elongation of quenched and tempered Thermold J alloy steel sheet at different temperatures.

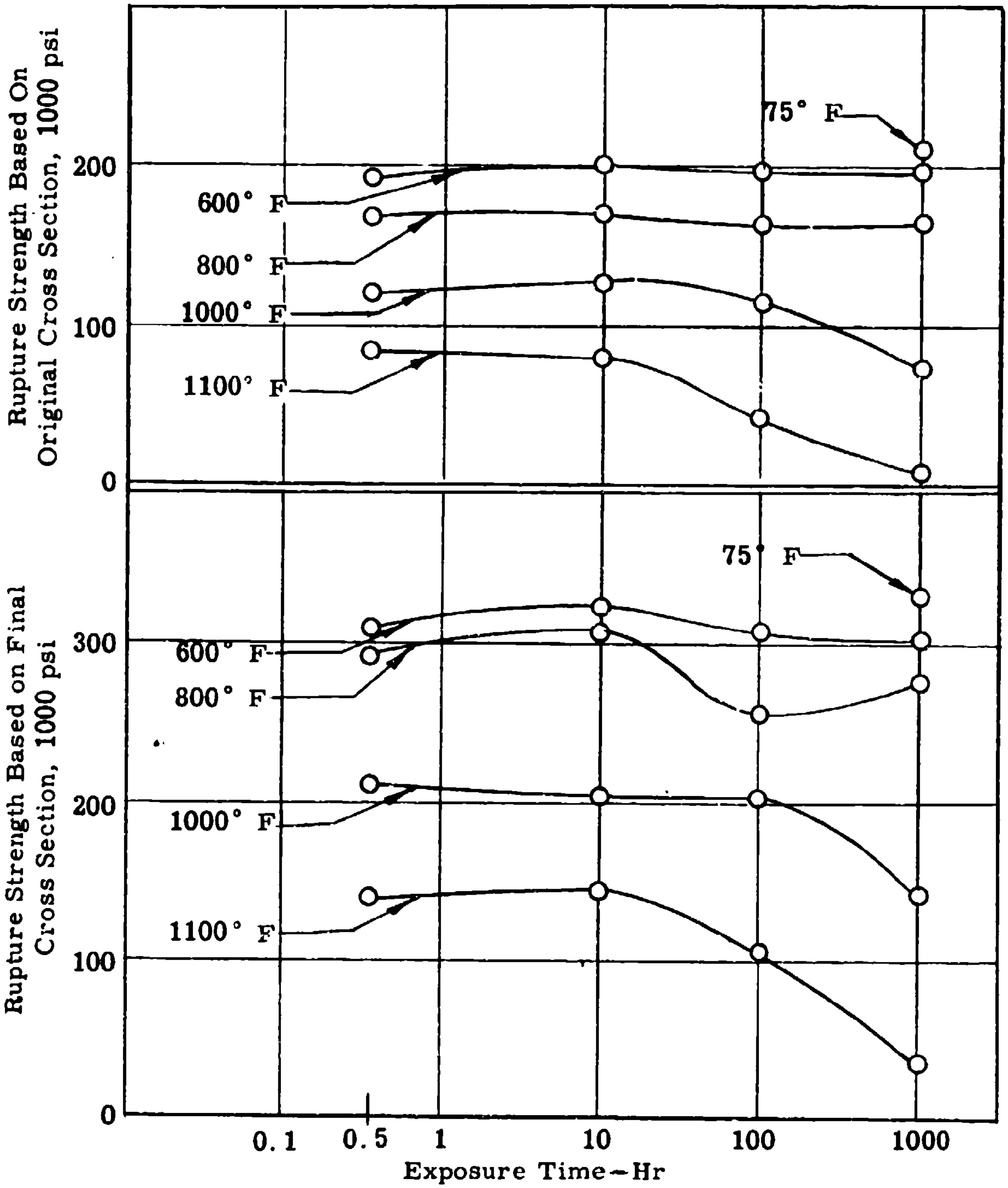


Fig. 60. Effect of exposure time on the tensile rupture strength of quenched and tempered Thermold J alloy steel sheet at different temperatures.

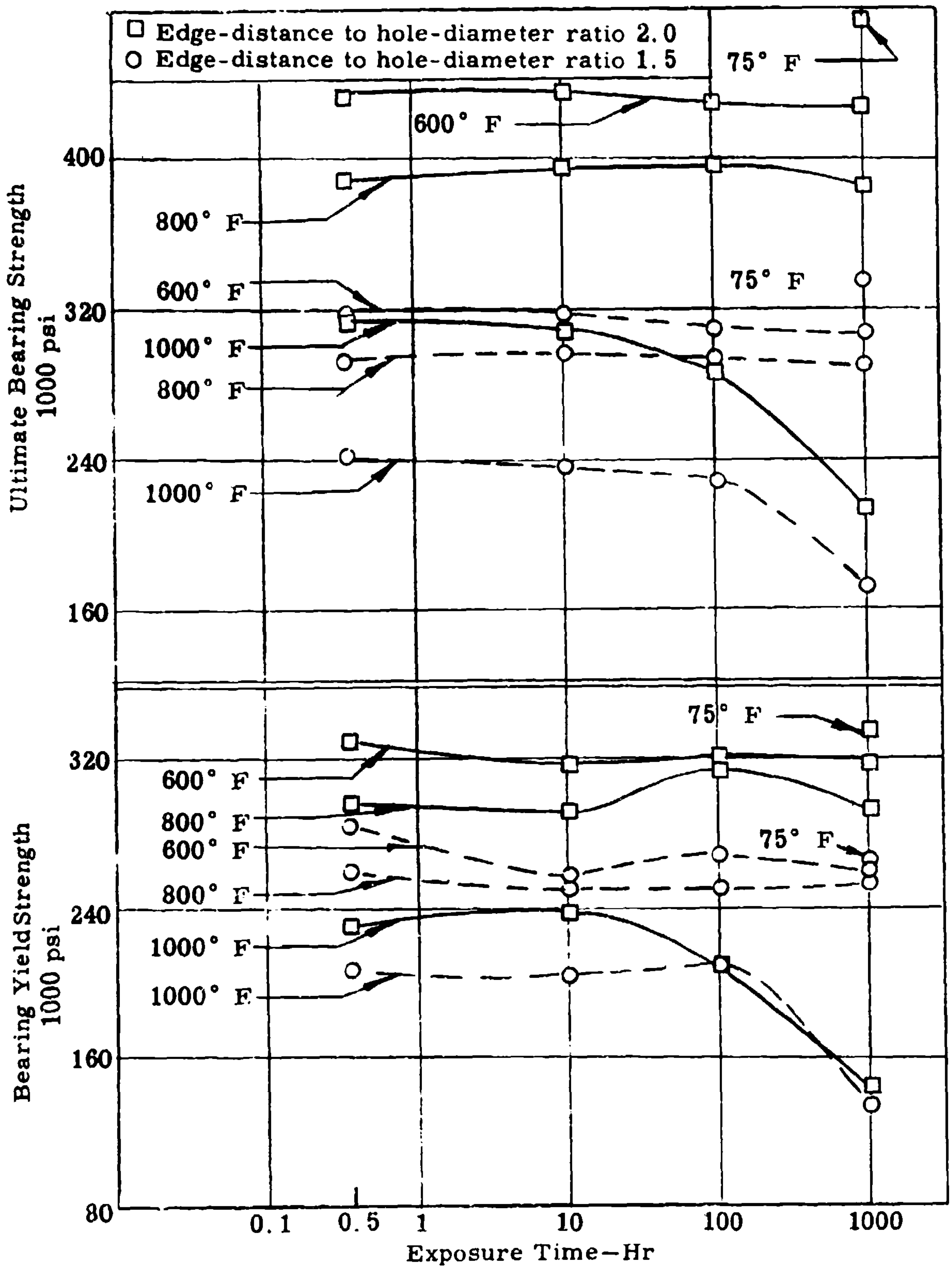


Fig. 61. Effect of exposure time on the bearing ultimate and yield strengths of quenched and tempered Thermold J alloy steel sheet at different temperatures

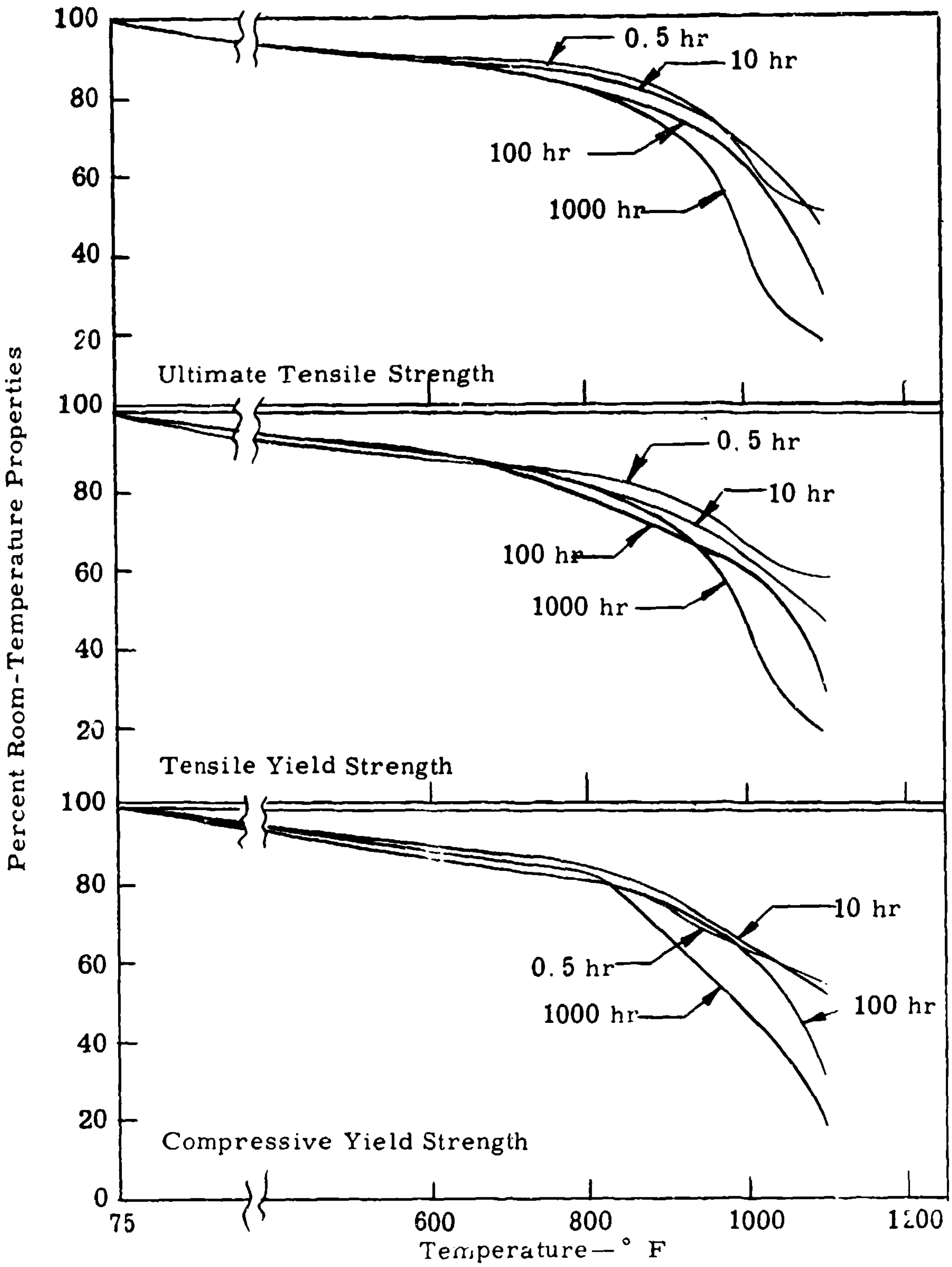


Fig. 62. Elevated-temperature strength properties as percent of room-temperature properties for quenched and tempered Thermold J alloy steel sheet at different exposure times.

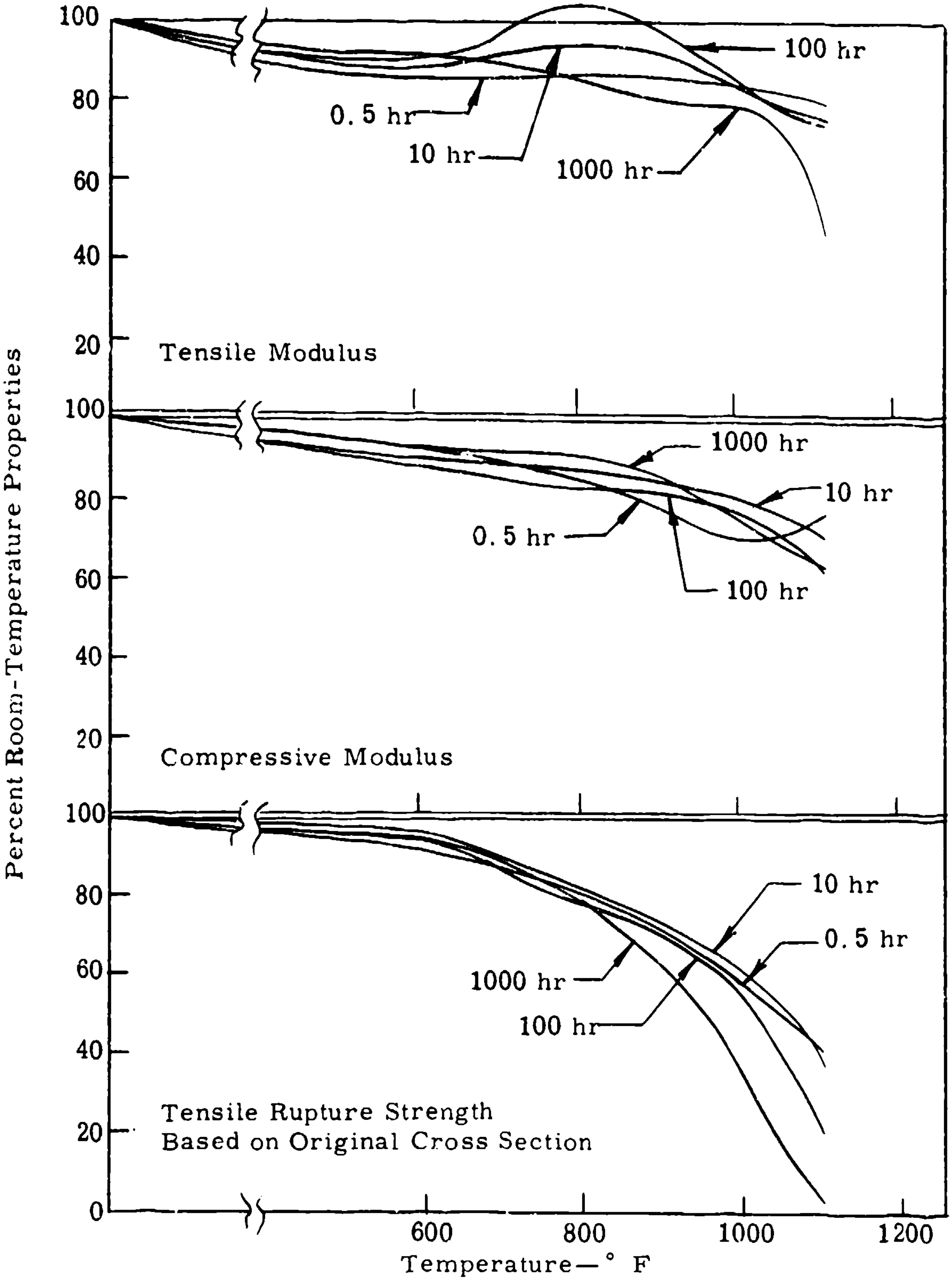


Fig. 63. Elevated-temperature properties as percent of room-temperature properties for quenched and tempered Thermold J alloy steel sheet at different exposure times.

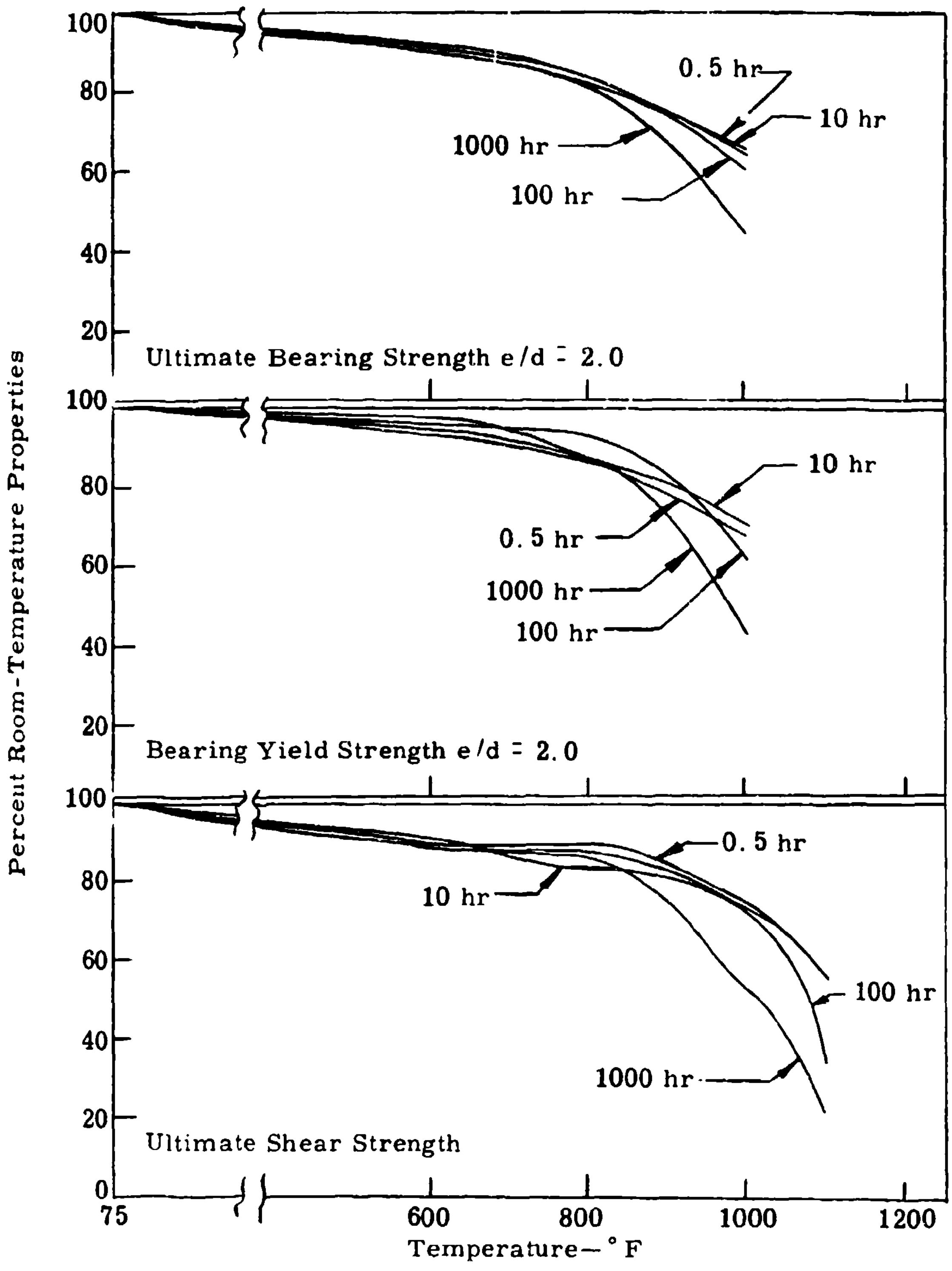


Fig. 64. Elevated-temperature strength properties as percent of room-temperature properties for quenched and tempered Thermold J alloy steel sheet at different exposure times.

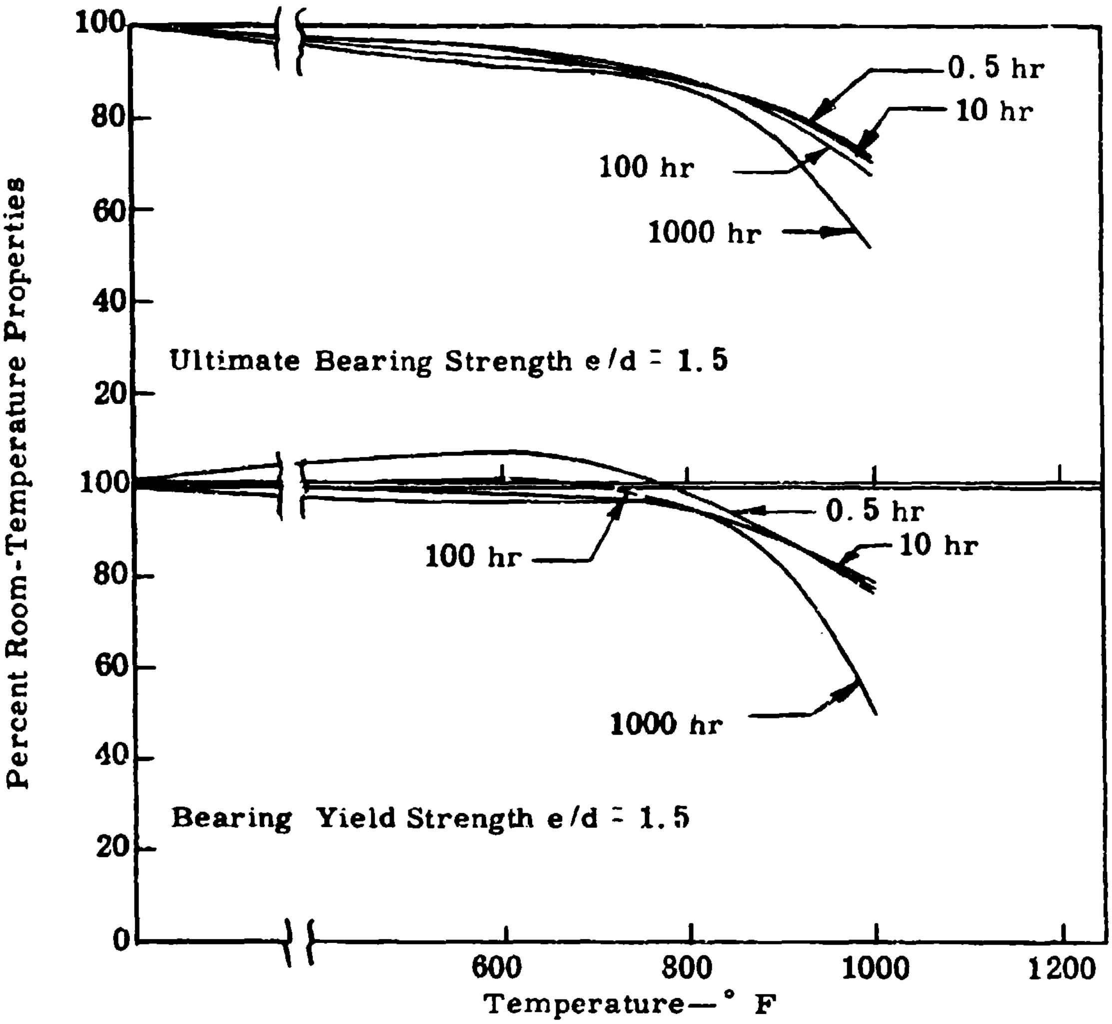


Fig. 65. Elevated-temperature strength properties as percent of room-temperature properties for quenched and tempered Thermold J alloy steel sheet at different exposure times.

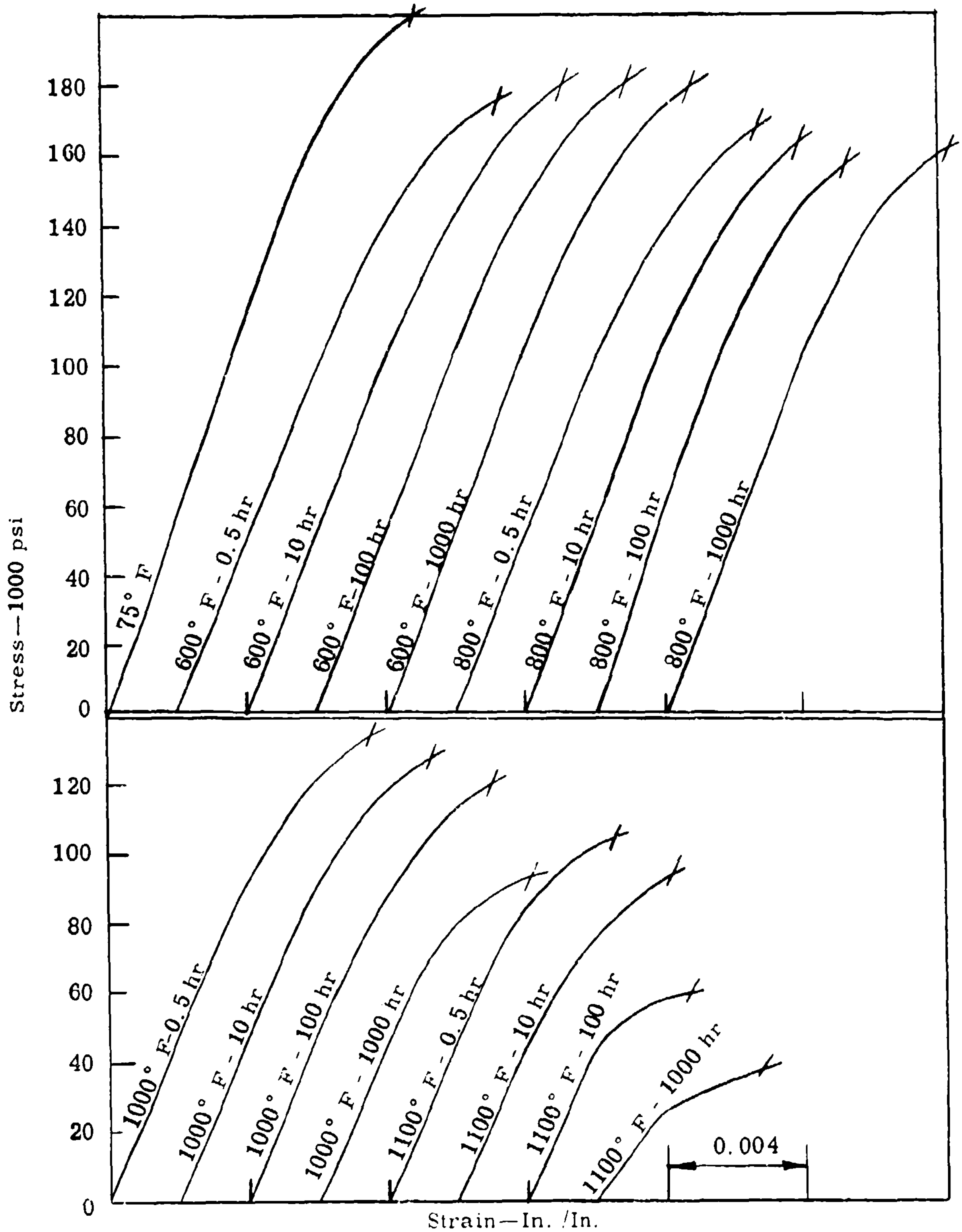


Fig. 66. Tensile stress-strain curves for quenched and tempered Thermold J alloy steel sheet at various temperatures and exposure times.

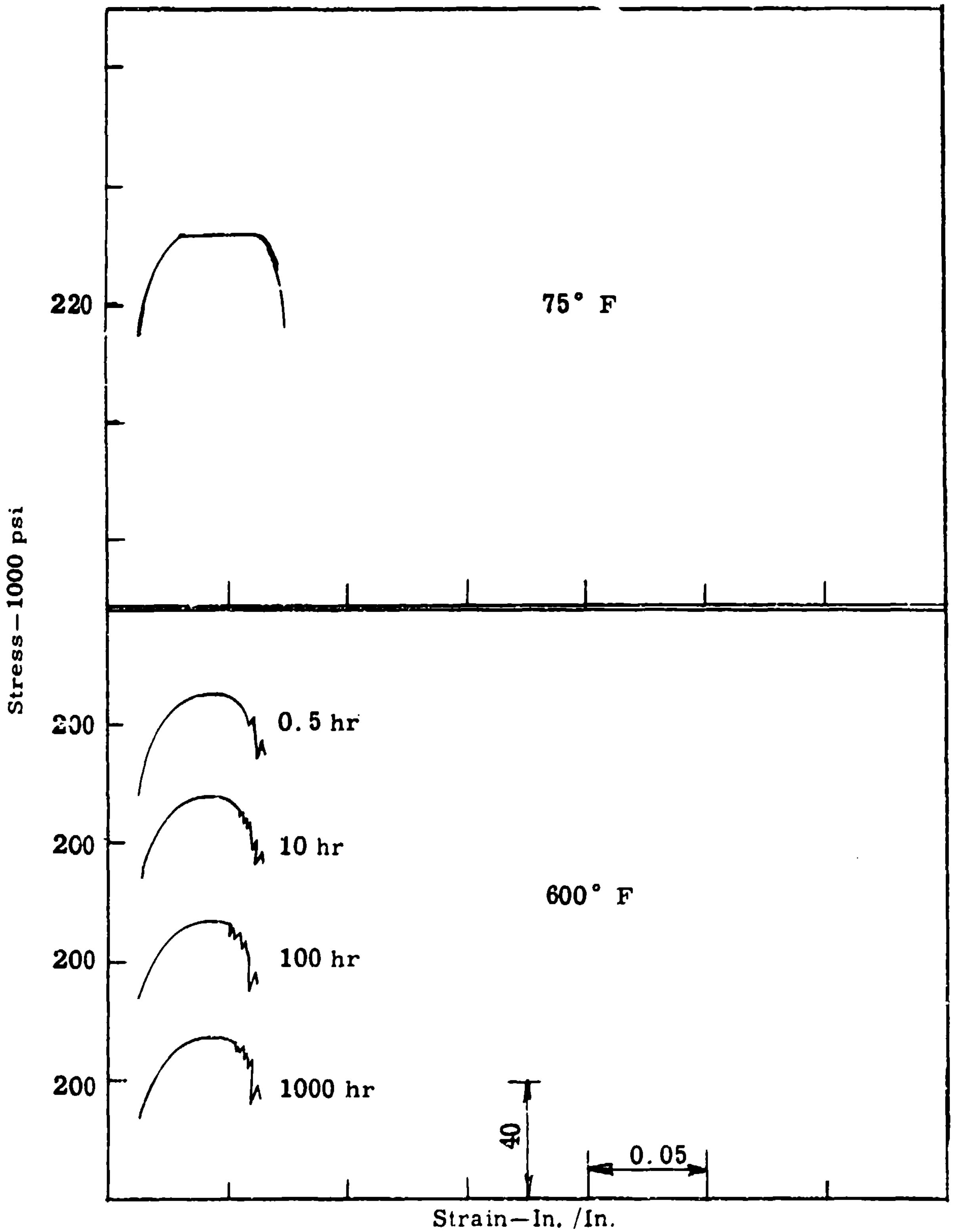


Fig. 67. Tensile postyield stress-strain curves for quenched and tempered Thermold J alloy steel sheet at various temperatures and exposure times.

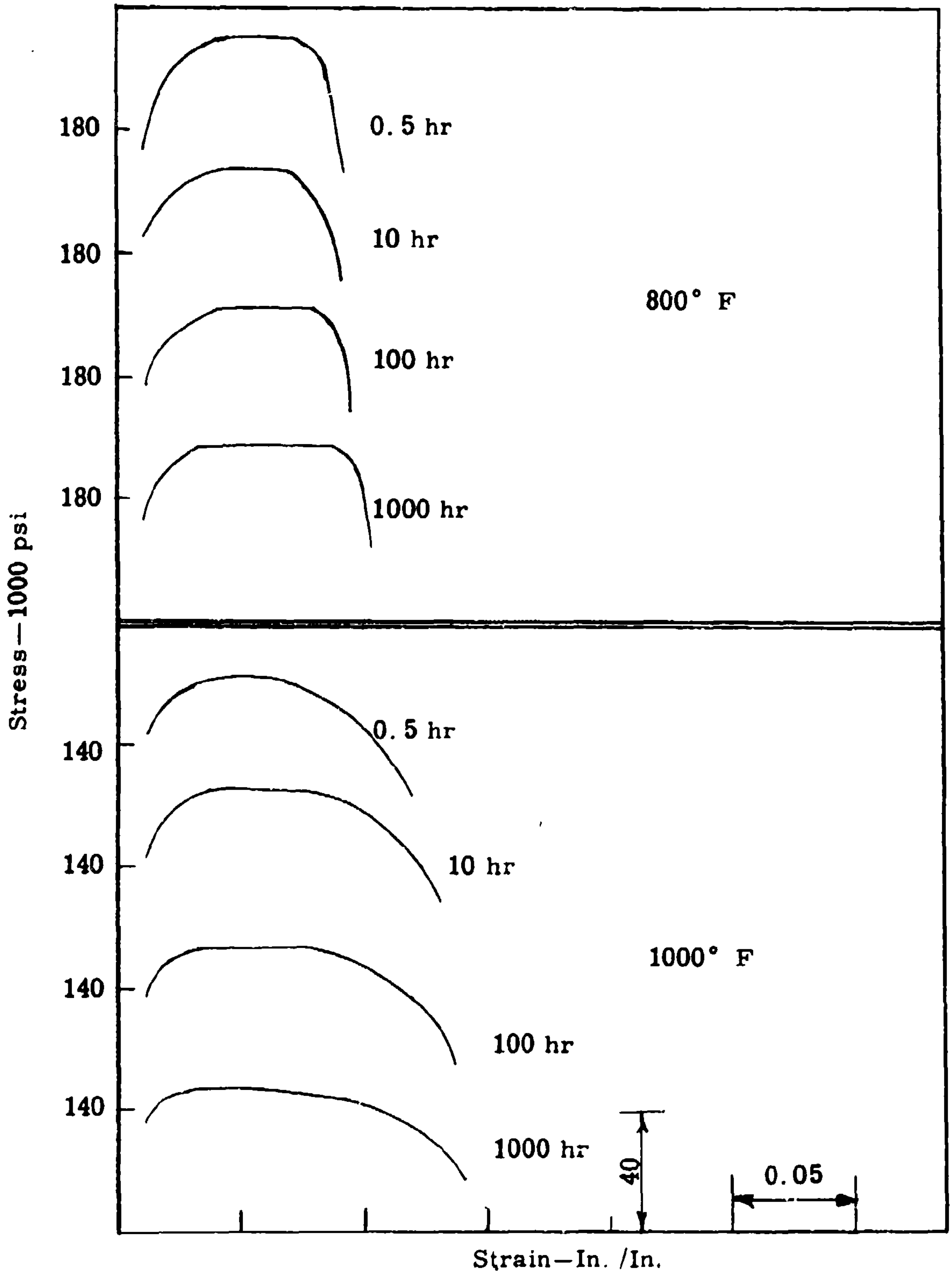


Fig. 68. Tensile postyield stress-strain curves for quenched and tempered Thermold J alloy steel sheet at various temperatures and exposure times.

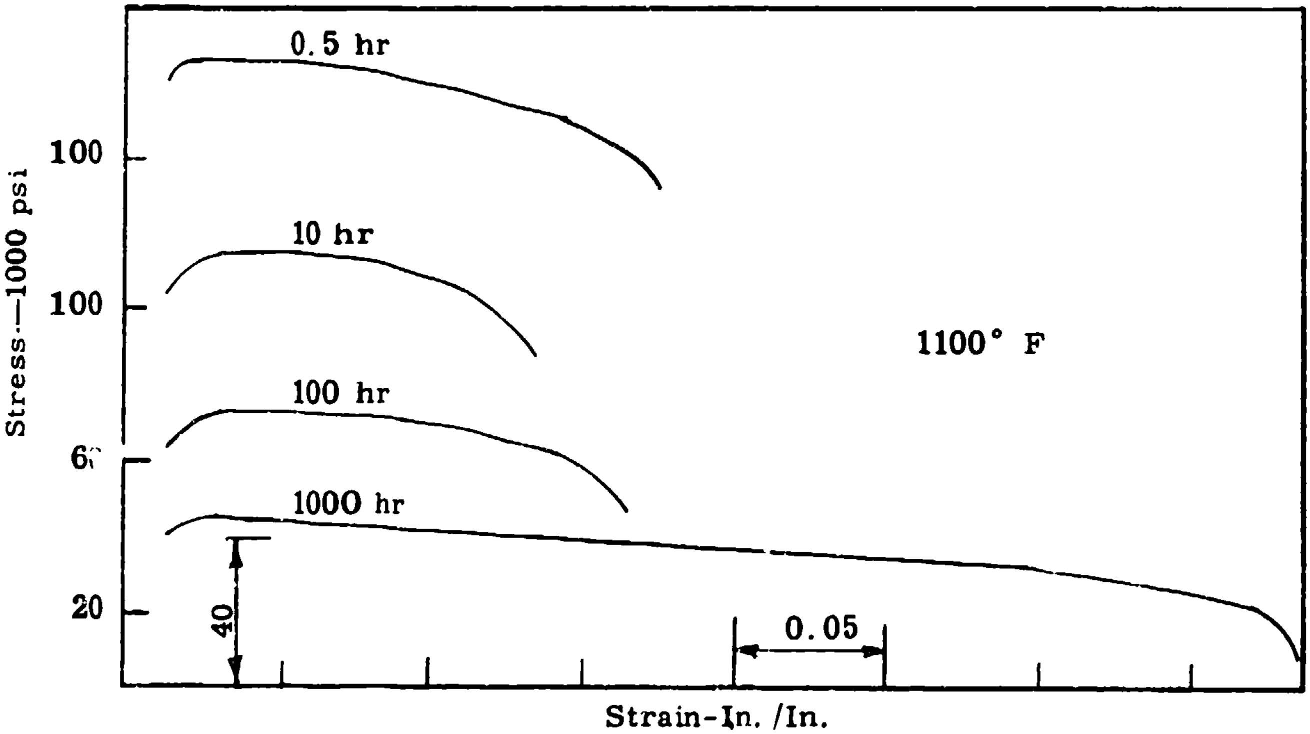


Fig. 69. Tensile postyield stress-strain curves for quenched and tempered Thermold J alloy steel sheet at various temperatures and exposure times.

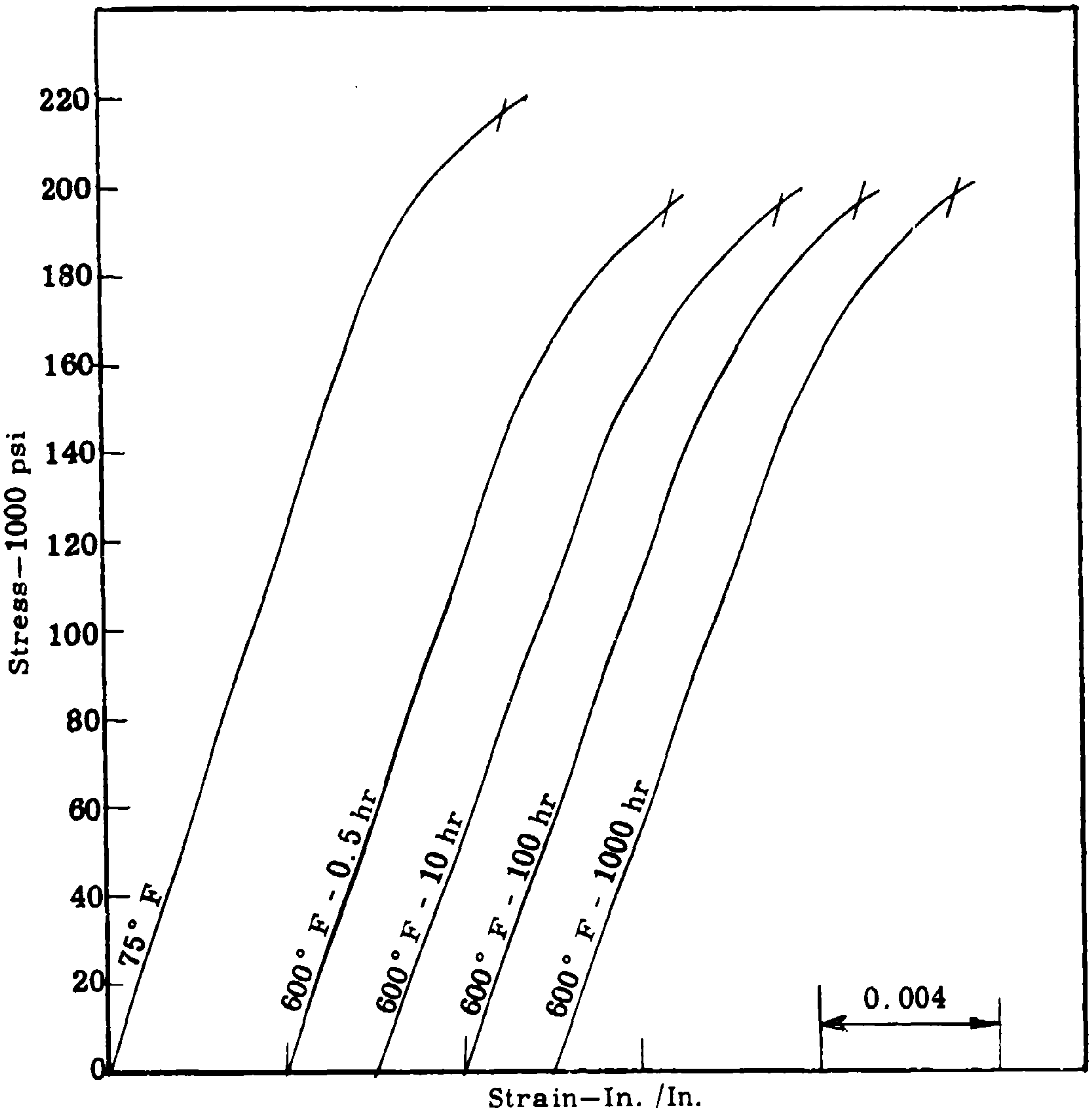


Fig. 70. Compressive stress-strain curves for quenched and tempered Thermold J alloy steel sheet at various temperatures and exposure times.

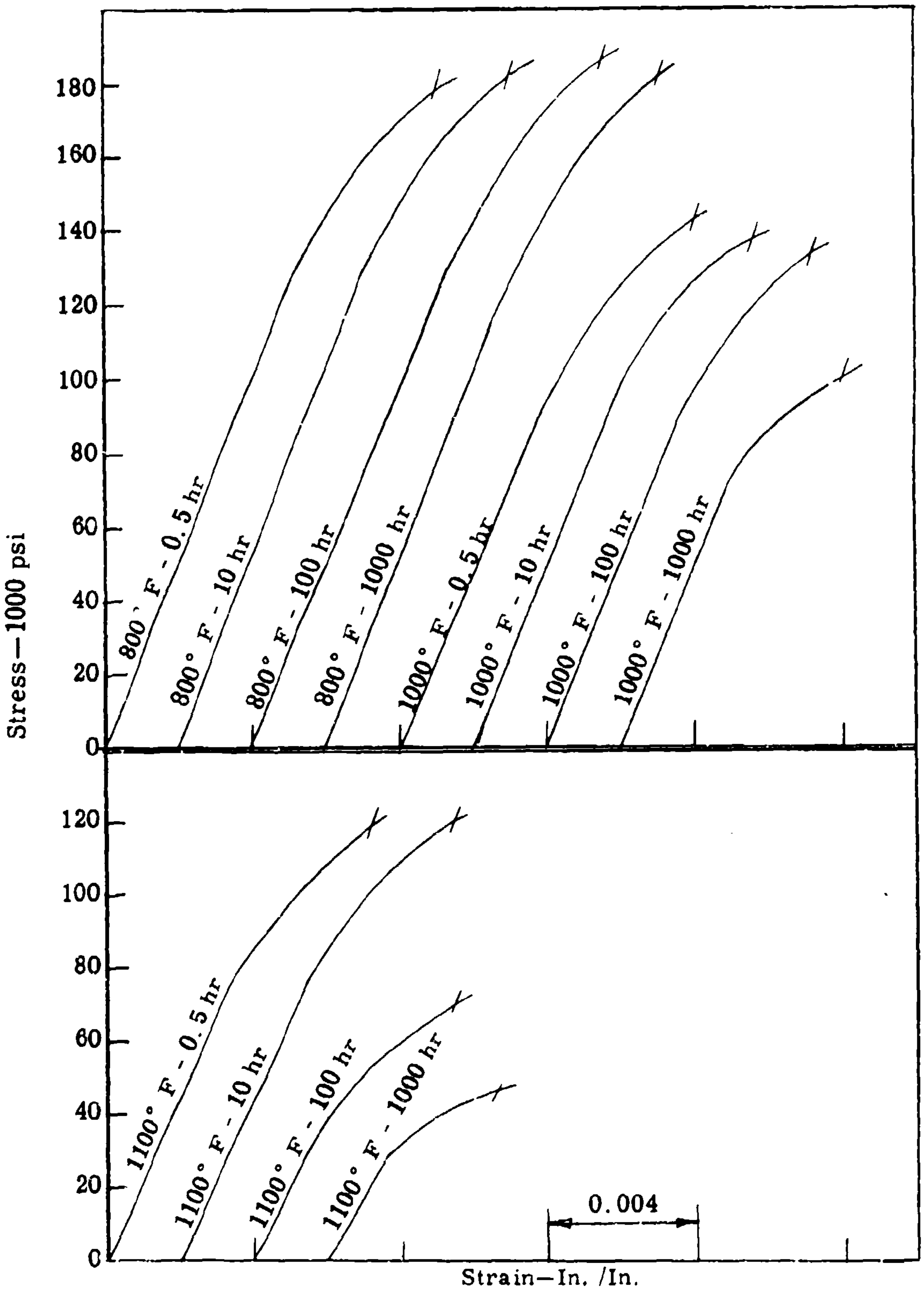


Fig. 71. Compressive stress-strain curves for quenched and tempered Thermold J alloy steel sheet at various temperatures and exposure times

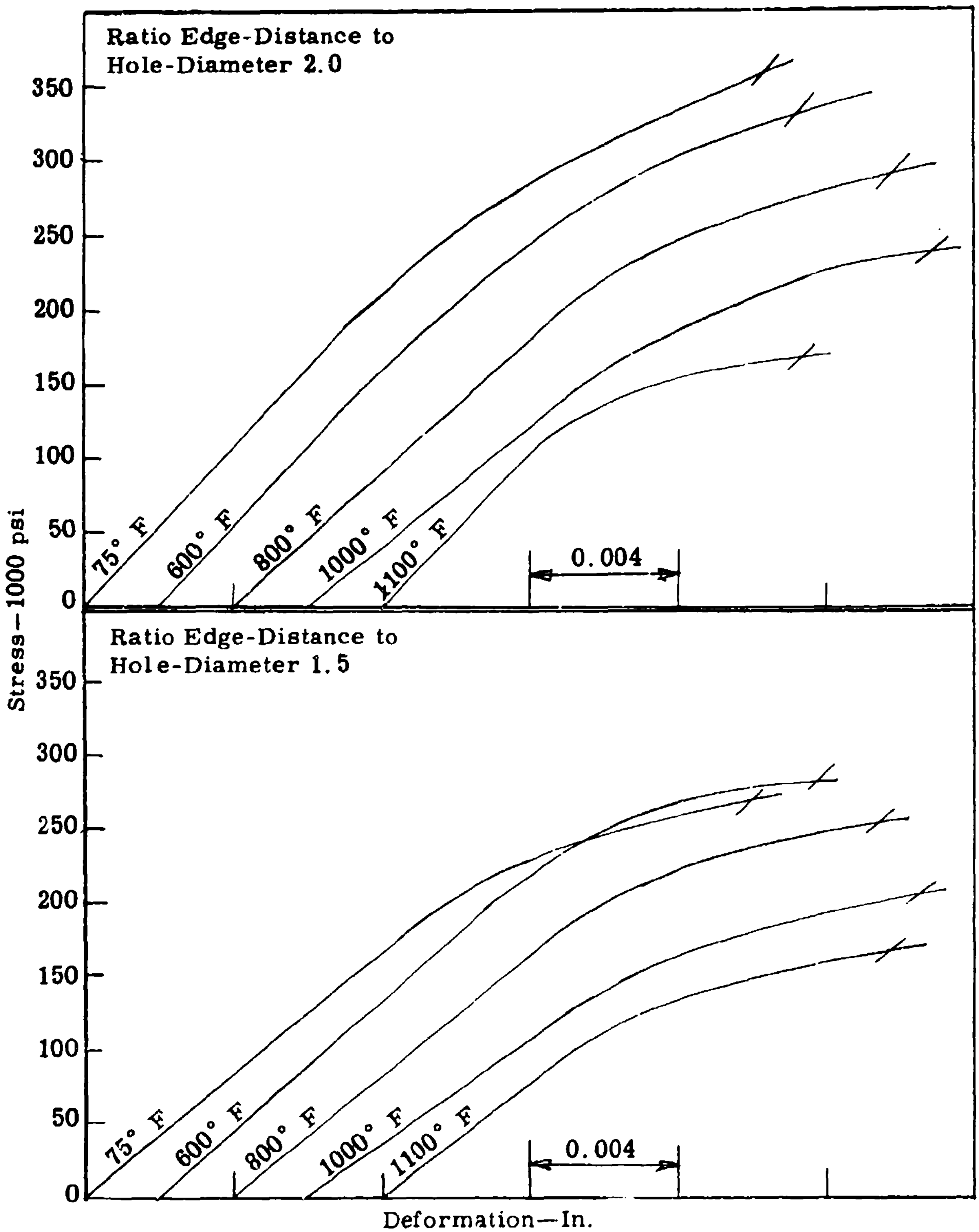


Fig. 72. Bearing stress-deformation curves for quenched and tempered Thermold J alloy steel sheet at various temperatures and one-half-hour exposure time

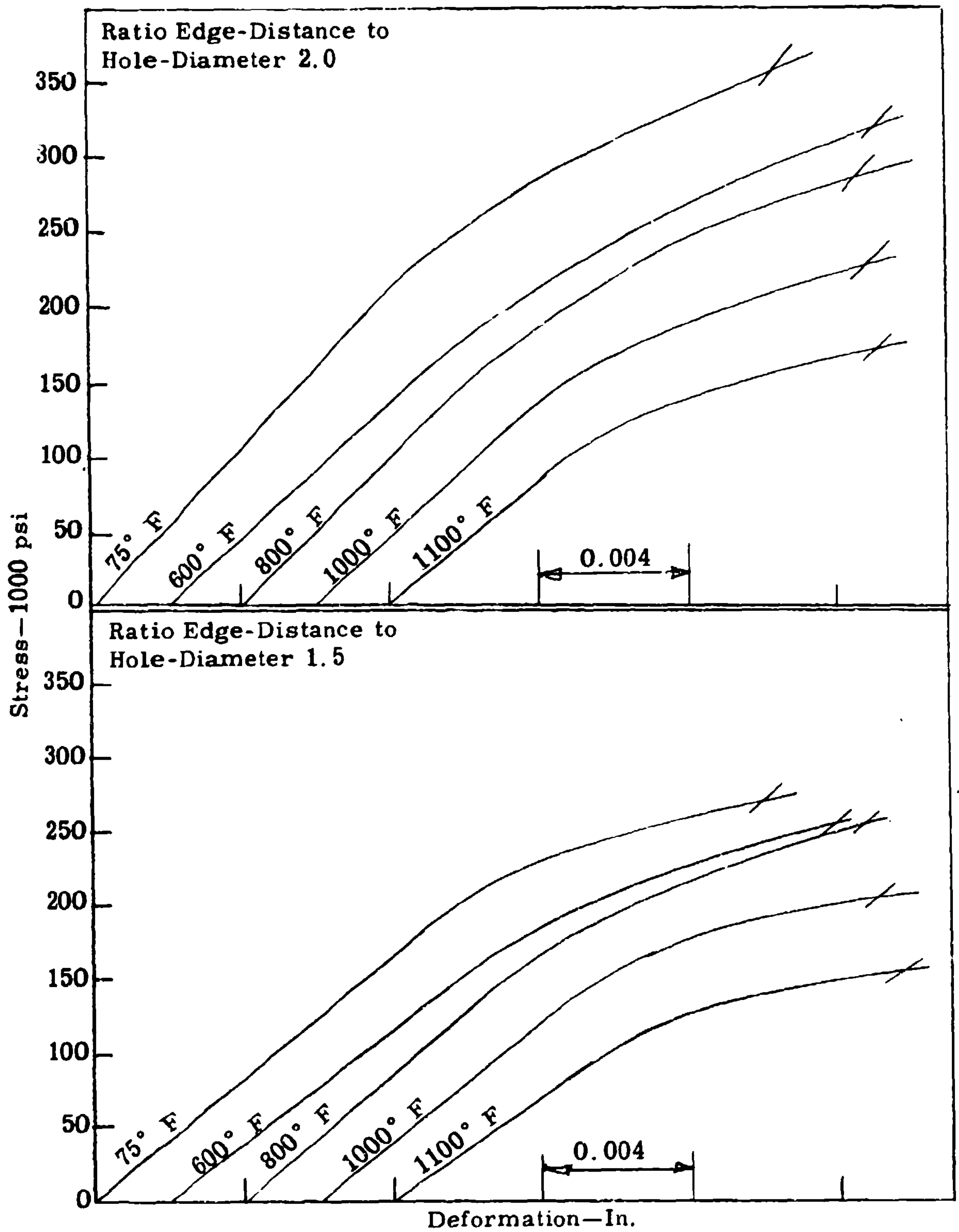


Fig. 73. Bearing stress-deformation curves for quenched and tempered Thermold J alloy steel sheet at various temperatures and ten-hour exposure time.

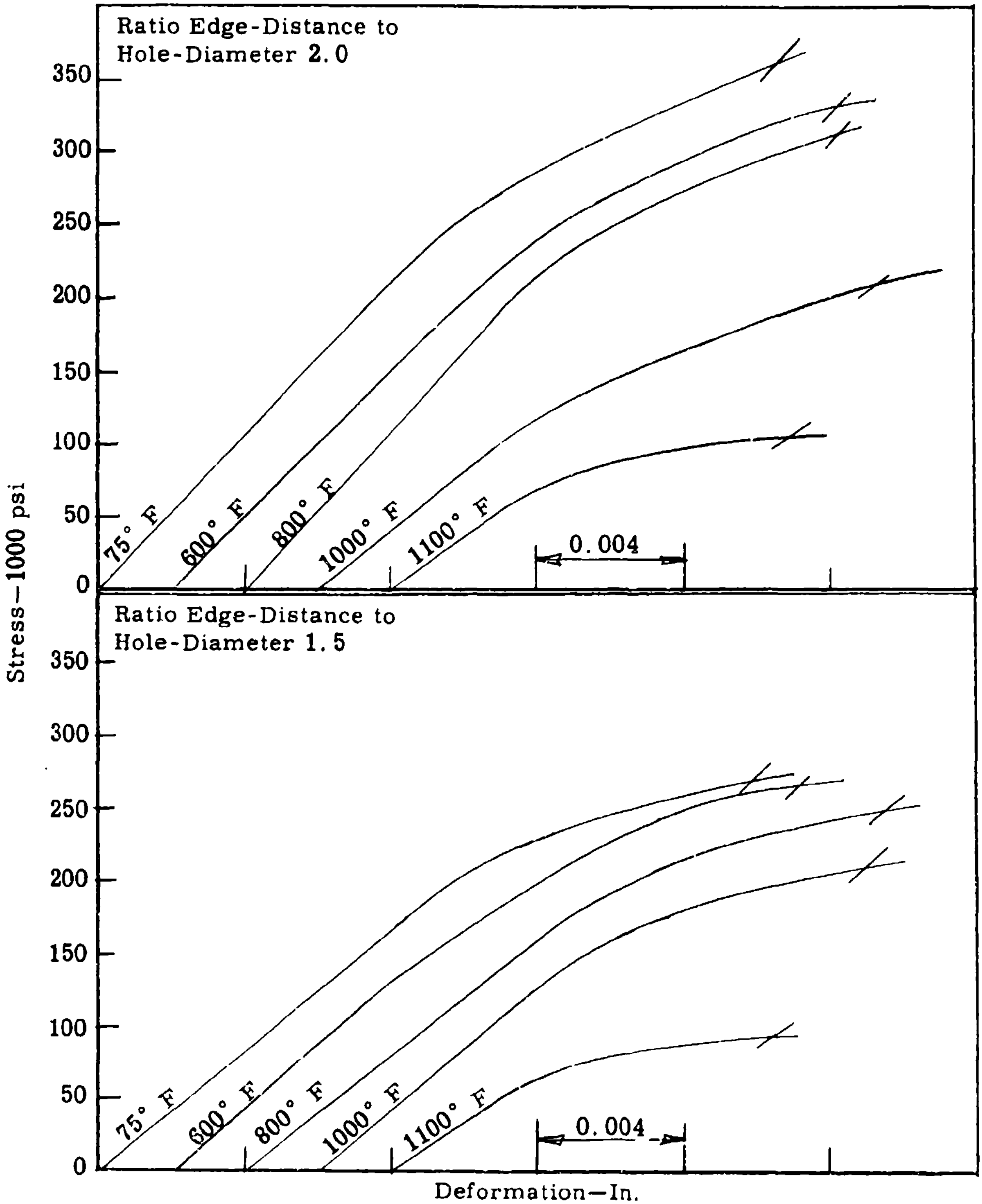


Fig. 74. Bearing stress-deformation curves for quenched and tempered Thermold J alloy steel sheet at various temperatures and one-hundred-hour exposure time.

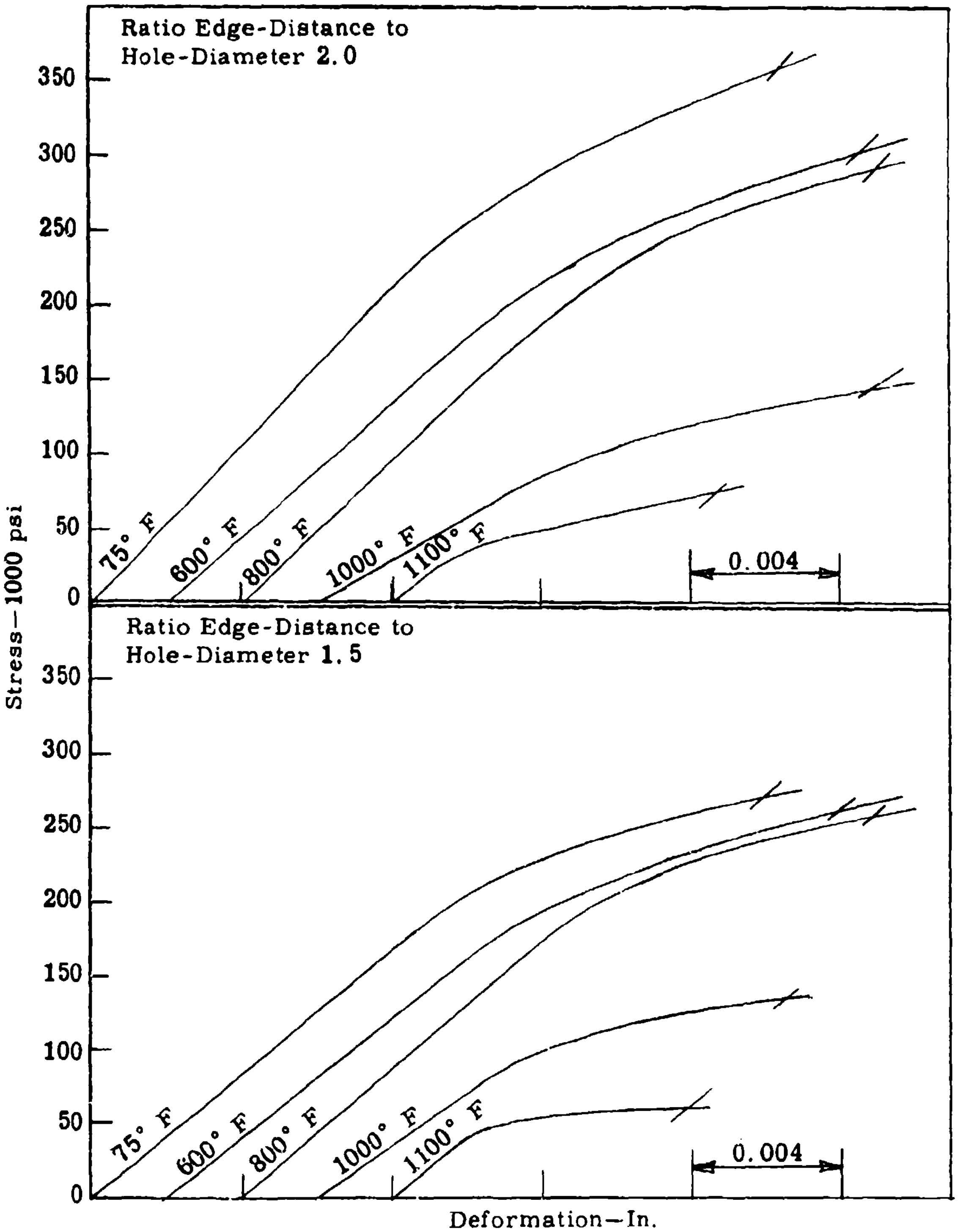


Fig. 75. Bearing stress-deformation curves for quenched and tempered Thermold J alloy steel sheet at various temperatures and one-thousand-hour exposure time.

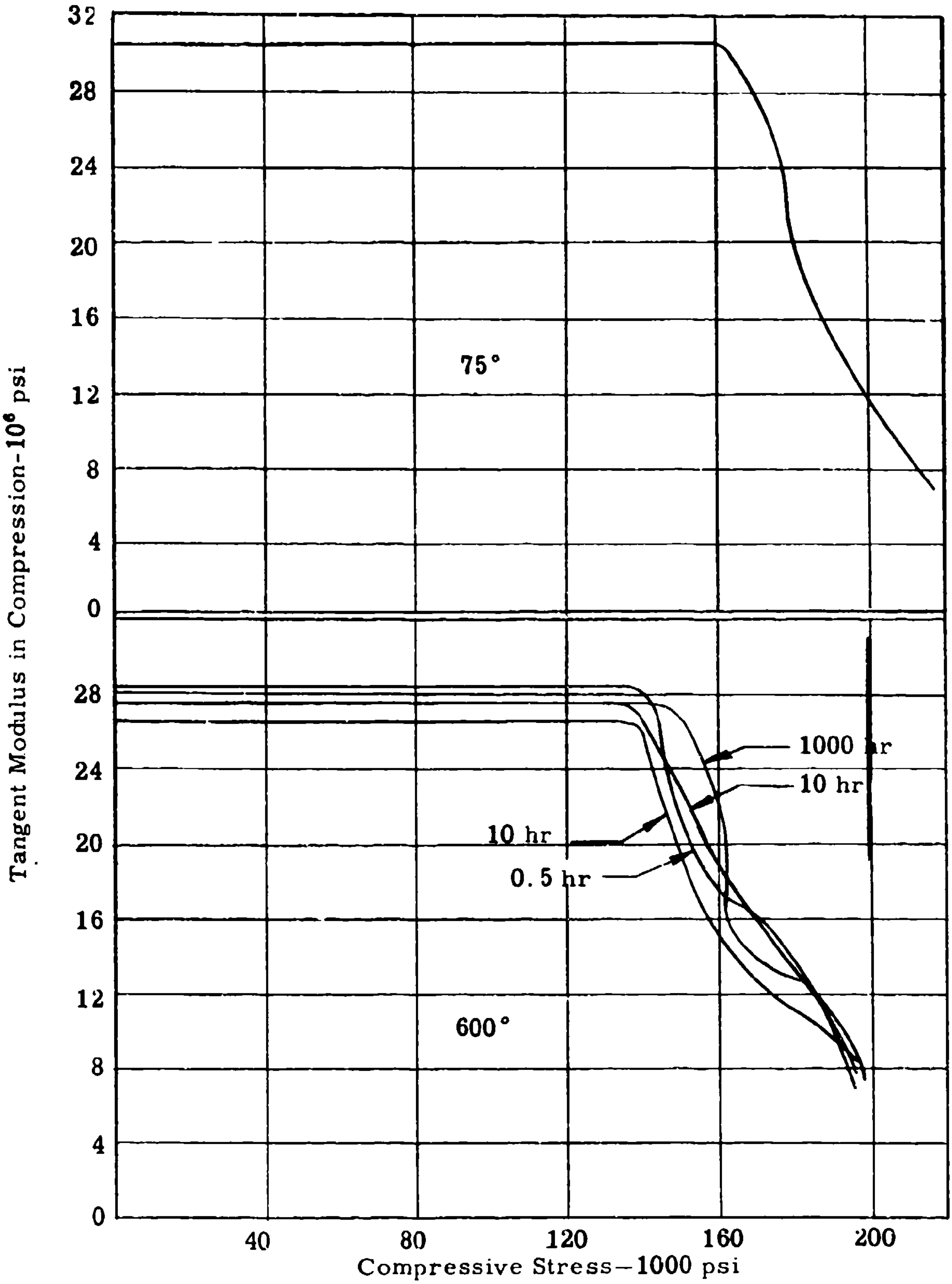


Fig. 76. Tangent-modulus vs. compressive-stress curves for quenched and tempered Thermold J alloy steel sheet at 75° F and 600° F and different exposure times.

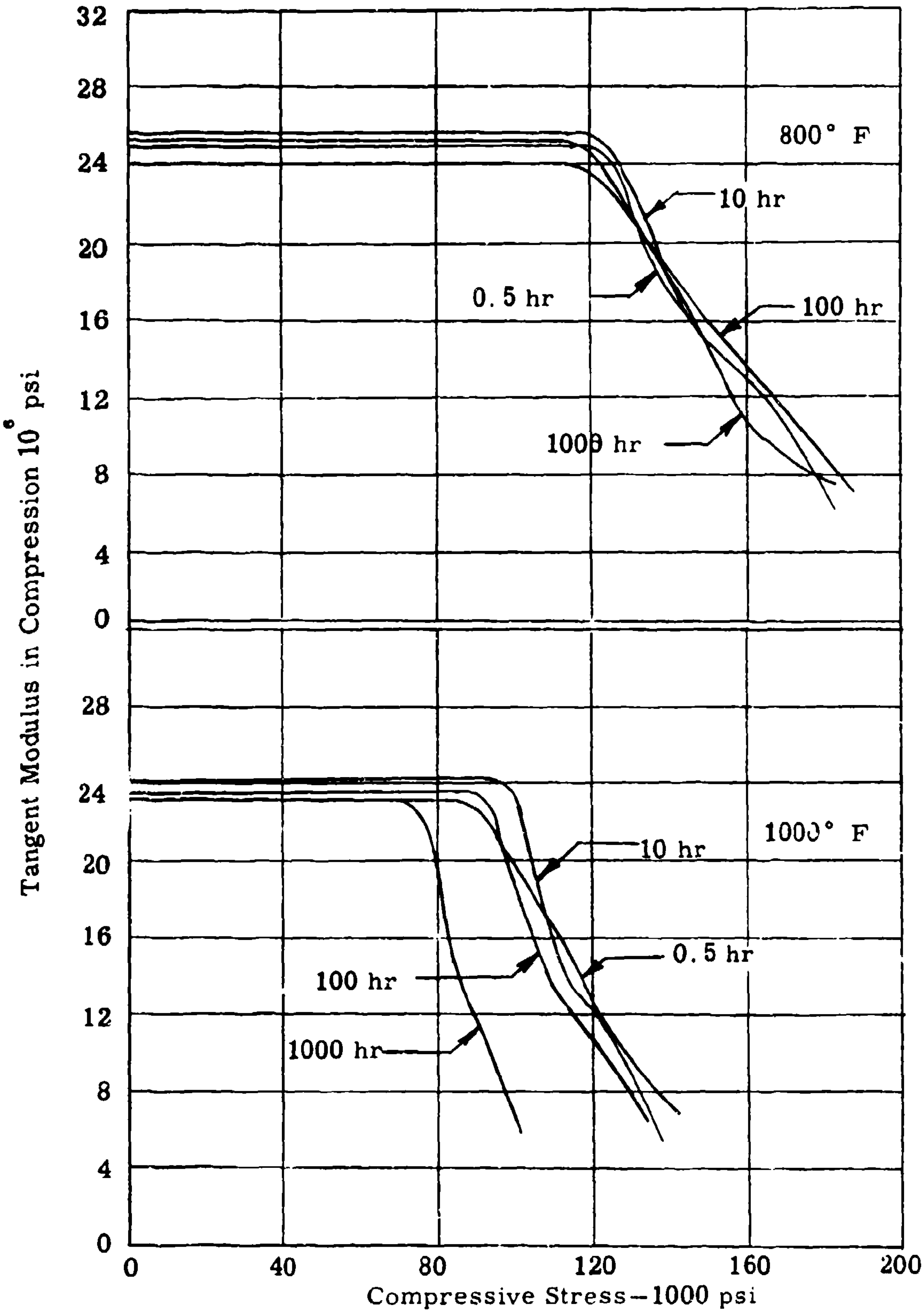


Fig. 77. Tangent-modulus vs. compressive-stress curves for quenched and tempered Thermold J alloy steel sheet at 800° F and 1000° F and different exposure times.

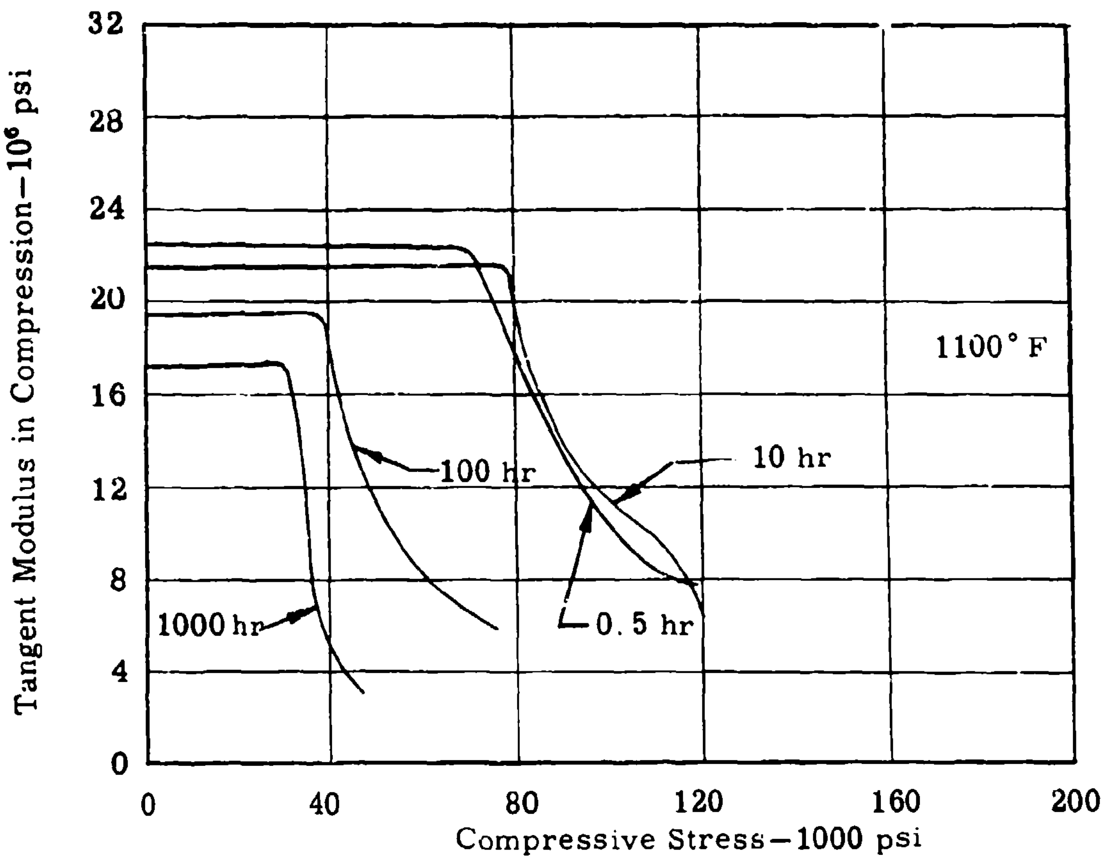


Fig. 78. Tangent modulus vs. compressive-stress curves for quenched and tempered Thermold J alloy steel sheet at 1100° F and different exposure times.

## Table 16

**Tensile Properties of 0.062-In Thermold J Alloy Steel[4] Sheet at Different Temperatures and Holding Times**

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| RT | | 195.2 | 234.0 | 29.1 | 6 | 53 | 201.0 | 344.0 |
| | | 206.0 | 244.5 | 28.7 | 7 | 52 | 213.5 | 325.0 |
| | | 201.0 | 246.0 | 28.4 | 6 | 53 | 216.0 | 321.0 |
| Avg | | 200.7 | 241.5 | 28.7 | 6 | 53 | 210.2 | 330.0 |
| 600 | 0.5 | 174.3 | 211.0 | 25.3 | 5 | 48 | 190.8 | 313.0 |
| | | 177.2 | 226.5 | 24.8 | 5 | 50 | 194.2 | 287.5 |
| | | 176.0 | 216.0 | 24.0 | 4 | 48 | 195.0 | 329.0 |
| Avg | | 175.8 | 217.8 | 24.7 | 5 | 49 | 193.3 | 309.8 |
| 600 | 10 | 182.2 | 216.2 | 25.7 | 5 | 47 | 194.8 | 313.0 |
| | | 180.2 | 217.0 | 24.4 | 5 | 55 | 205.5 | 359.0 |
| | | 179.5 | 217.0 | 25.9 | 5 | 47 | 205.0 | 297.0 |
| Avg | | 180.6 | 216.7 | 25.3 | 5 | 49 | 201.8 | 323.0 |
| 600 | 100 | 188.2 | 217.0 | 25.1 | 5 | 50 | 194.0 | 311.5 |
| | | 179.0 | 216.5 | 26.5 | 5 | 52 | 201.5 | 327.0 |
| | | 177.0 | 214.0 | 26.1 | 5 | 50 | 197.4 | 285.0 |
| Avg | | 181.4 | 216.2 | 25.9 | 5 | 51 | 197.6 | 307.8 |
| 600 | 1000 | 179.0 | 215.0 | 26.5 | 5 | 50 | 195.6 | 299.0 |
| | | 180.0 | 214.5 | 26.7 | 5 | 49 | 201.0 | 296.0 |
| | | 181.5 | 216.0 | 25.1 | 5 | 52 | 196.6 | 311.0 |
| Avg | | 180.2 | 215.2 | 26.1 | 5 | 50 | 197.7 | 302.0 |

Table 16 (continued)

Tensile Properties of 0.062-In. Thermold J Alloy Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 800 | 0.5 | 174.5 | 210.0 | 25.0 | 8 | 52 | 168.0 | 323.0 |
| | | 166.5 | 210.0 | 23.8 | 8 | 51 | 166.5 | 278.0 |
| | | 165.5 | 206.0 | 25.6 | 8 | 51 | 171.5 | 280.0 |
| Avg | | 168.8 | 208.7 | 24.8 | 8 | 51 | 168.7 | 293.7 |
| 800 | 10 | 166.0 | 207.0 | 30.8 | 9 | 50 | 171.5 | 312.0 |
| | | 163.5 | 204.0 | 25.2 | 8 | 51 | 169.0 | 294.0 |
| | | 161.0 | 207.0 | 24.9 | 8 | 51 | 172.0 | 316.0 |
| Avg | | 163.5 | 206.0 | 27.0 | 8 | 51 | 170.8 | 307.3 |
| 800 | 100 | — | 204.0 | 29.0 | 9 | 54 | 166.0 | 208.0 |
| | | 157.0 | 194.0 | 29.5 | 10 | 53 | 157.0 | 294.0 |
| | | 157.0 | 202.5 | 31.1 | 8 | 51 | 169.0 | 268.0 |
| Avg | | 157.0 | 200.2 | 29.9 | 9 | 53 | 164.0 | 256.7 |
| 800 | 1000 | 160.0 | 198.0 | 23.1 | 9 | 51 | 165.0 | 278.0 |
| | | 159.5 | 193.0 | 24.0 | 9 | 52 | 167.5 | 279.5 |
| | | 172.5 | 198.5 | 25.6 | 9 | 52 | 161.0 | 270.5 |
| Avg | | 164.0 | 196.5 | 24.2 | 9 | 52 | 164.5 | 276.0 |
| 1000 | 0.5 | 140.0 | 162.0 | 23.2 | 11 | 55 | 124.0 | 214.5 |
| | | 134.0 | 157.5 | 24.9 | 11 | 56 | 116.5 | 202.0 |
| | | 131.0 | 161.0 | — | 10 | 55 | 123.5 | 218.0 |
| Avg | | 135.0 | 160.2 | 24.0 | 11 | 55 | 121.3 | 211.5 |

Table 16 (continued)

Tensile Properties of 0.062-In. Thermold J Alloy Steel* Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 1000 | 10 | 128.0 | 164.0 | 24.2 | 15 | 49 | 124.0 | 214.0 |
| | | 129.0 | 162.5 | 23.8 | 11 | 50 | 128.5 | 200.0 |
| | | 128.0 | 166.0 | 23.8 | 10 | 49 | 128.5 | 196.0 |
| Avg | | 128.3 | 164.2 | 23.9 | 12 | 49 | 127.0 | 203.3 |
| 1000 | 100 | 114.8 | 149.5 | 27.2 | 13 | 49 | 122.2 | 205.0 |
| | | 125.5 | 153.9 | 22.8 | 13 | 50 | 115.0 | 217.0 |
| | | 122.0 | 153.0 | 22.0 | 13 | 52 | 108.9 | 187.0 |
| Avg | | 120.8 | 152.1 | 24.0 | 13 | 50 | 115.4 | 203.0 |
| 1000 | 1000 | 93.9 | 107.5 | 21.4 | 14 | 44 | 78.8 | 141.0 |
| | | 100.2 | 110.2 | 22.4 | 12 | 47 | 84.8 | 144.4 |
| | | 87.0 | 100.0 | 24.4 | 14 | 47 | 58.5 | 143.0 |
| Avg | | 93.7 | 105.9 | 22.7 | 13 | 45 | 74.0 | 142.8 |
| 1100 | 0.5 | 105.0 | 122.0 | 22.9 | 16 | 49 | 82.5 | 149.2 |
| | | 116.0 | 123.5 | 22.9 | 17 | 49 | 79.5 | 127.5 |
| | | 114.0 | 126.0 | 22.9 | 17 | 49 | 92.6 | 143.0 |
| Avg | | 111.7 | 123.8 | 22.9 | 17 | 49 | 84.9 | 139.9 |
| 1100 | 10 | 100.5 | 115.2 | 20.5 | 8 | 51 | 83.2 | 145.5 |
| | | 94.5 | 113.2 | 23.0 | 13 | 52 | 70.6 | 163.2 |
| | | 91.3 | 115.5 | 22.0 | 9 | 52 | 87.4 | 124.0 |
| Avg | | 95.4 | 114.6 | 21.8 | 10 | 52 | 80.4 | 144.2 |

Table 16 (continued)

Tensile Properties of 0.062-In. Thermold J Alloy Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 1100 | 100 | 58.3 | 74.8 | 23.9 | 16 | 49 | 43.2 | 102.5 |
| | | 59.8 | 75.2 | 17.8 | 12 | 50 | 44.5 | 107.0 |
| | | 59.8 | 73.0 | 22.0 | 11 | 50 | 43.7 | 106.5 |
| Avg | | 59.3 | 74.3 | 21.2 | 13 | 50 | 43.8 | 105.3 |
| 1100 | 1000 | 37.5 | 43.7 | 13.8 | 33 | 24 | 7.3 | 33.5 |
| | | 37.5 | 44.5 | 13.7 | 35 | 25 | 7.8 | 35.6 |
| | | 37.5 | 44.6 | 12.9 | 33 | 24 | 7.8 | 36.7 |
| Avg | | 37.5 | 44.3 | 13.5 | 34 | 24 | 7.6 | 35.3 |

1. Hardness determinations made at room temperature after tests.
2. Rupture strength based on original cross section.
3. Rupture strength based on final cross section.
4. Heat treatment — 1850° F 15 min argon atmosphere, A. C., 1000° F 2 hr, 1000° F 2 hr, A. C.

Table 17

Tensile Strength of 3/16-In. Thermold J Alloy Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC |
| RT | | | | | | | 270.0 | 49 |
| | | | | | | | 271.0 | 46 |
| | | | | | | | 268.0 | 48 |
| | | | | | | | 263.0 | 46 |
| Avg | | | | | | | 268.0 | 47 |
| 600 | 237.0 | 50 | 242.0 | 50 | 239.0 | 50 | 242.0 | 50 |
| | 238.0 | 48 | 243.0 | 51 | 242.0 | 46 | 244.0 | 51 |
| | 240.0 | 49 | 242.0 | 50 | 240.0 | 46 | 243.0 | 50 |
| Avg | 238.3 | 49 | 242.7 | 50 | 240.3 | 47 | 243.0 | 50 |
| 800 | 218.0 | 46 | 217.5 | 47 | 222.0 | 48 | 222.2 | 51 |
| | 218.0 | 48 | 217.0 | 48 | 221.0 | 49 | 222.0 | 50 |
| | – | – | 219.0 | 48 | 222.0 | 49 | 220.0 | 48 |
| Avg | 218.0 | 47 | 217.8 | 48 | 221.7 | 49 | 221.4 | 50 |

Table 17(continued)

Tensile Strength of 3/16-In. Thermold J Alloy Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp ° F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC |
| 1000 | 172.0 | 49 | 178.0 | 50 | 164.8 | 51 | 100.5 | 41 |
| | 167.0 | 50 | 179.0 | 49 | 169.0 | 49 | 100.0 | 42 |
| | 183.0 | 49 | 174.0 | 49 | 168.0 | 49 | 99.0 | 42 |
| Avg | 174.0 | 49 | 177.0 | 49 | 167.3 | 50 | 99.8 | 42 |
| 1100 | 134.9 | 49 | 115.0 | 47 | 66.0 | 42 | 48.2 | 23 |
| | 132.0 | 46 | 114.0 | 47 | 67.5 | 42 | 48.0 | 23 |
| | 130.2 | 49 | 118.7 | 46 | 70.0 | 42 | 48.0 | 23 |
| Avg | 132.4 | 48 | 115.9 | 47 | 67.8 | 42 | 48.1 | 23 |

1. Ultimate tensile strength
2. Hardness determinations made at room temperature after tests.
3. Heat treatment – 1850° F 15 min argon atmosphere, A. C., 1000° F 2 hr, 1000° F 2 hr, A. C.

Table 18

Compressive Properties of 0.062-In. Thermold J Alloy Steel[3] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp ° F | CYS 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| RT | | | | | | | | | | 222.2 | 28.7 | 48 |
| | | | | | | | | | | 217.0 | 30.5 | 47 |
| | | | | | | | | | | 223.0 | 30.8 | 46 |
| Avg | | | | | | | | | | 220.7 | 30.0 | 47 |
| 600 | 196.0 | 28.4 | 49 | 196.5 | 26.6 | 49 | 196.5 | 29.1 | 49 | 198.0 | 27.9 | 49 |
| | 188.5 | 26.5 | 48 | 202.0 | 27.5 | 51 | 198.5 | 27.5 | 50 | 195.5 | 28.7 | 50 |
| | 188.8 | 28.4 | 49 | 198.5 | 27.0 | 51 | 201.0 | 23.1 | 49 | 198.0 | 27.4 | 49 |
| Avg | 191.1 | 27.8 | 49 | 199.0 | 27.0 | 50 | 198.7 | 26.6 | 49 | 197.2 | 28.0 | 49 |
| 800 | 182.5 | 25.8 | 50 | 191.0 | 29.4 | 47 | 187.0 | 24.1 | 50 | 183.2 | 25.2 | 50 |
| | 180.3 | 26.2 | 49 | 183.4 | 23.6 | 48 | 176.2 | 26.6 | 48 | 184.5 | 27.1 | 49 |
| | 178.8 | 24.9 | 49 | 182.2 | 25.6 | 48 | 176.5 | 23.9 | 46 | 183.8 | 29.9 | 49 |
| Avg | 180.5 | 25.6 | 49 | 185.5 | 26.2 | 48 | 179.9 | 24.9 | 48 | 183.8 | 27.4 | 49 |
| 1000 | 141.2 | 18.4 | 48 | 138.0 | 24.2 | 49 | 138.0 | 24.9 | 49 | 101.0 | 23.3 | 46 |
| | 142.2 | 23.2 | 48 | 146.0 | 22.5 | 49 | 134.0 | 23.7 | 47 | 104.5 | 17.1 | 47 |
| | 132.0 | 21.5 | 48 | 147.0 | 25.7 | 49 | 142.0 | 21.1 | 48 | 100.0 | 26.5 | 47 |
| Avg | 138.5 | 21.0 | 48 | 143.7 | 24.1 | 49 | 138.0 | 23.2 | 48 | 101.8 | 22.3 | 47 |

Table 18 (continued)

Compressive Properties of 0.062-In. Thermold J Alloy Steel[3] Sheet at Different Temperatures and Holding Times

| Hold. Time Hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | CYS[1] 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| 1100 | 120.8 | 22.4 | 49 | 120.0 | 21.6 | 49 | 71.5 | 20.4 | 39 | 46.5 | 17.4 | 20 |
| | 118.6 | 22.5 | 48 | 107.0 | 22.0 | 45 | 65.9 | 16.4 | 39 | 42.7 | 22.9 | 22 |
| | 121.5 | 24.4 | 48 | 124.0 | 20.7 | 47 | 70.6 | 19.6 | 40 | 39.0 | 17.6 | 21 |
| Avg | 120.3 | 23.1 | 48 | 117.0 | 21.4 | 47 | 69.3 | 18.8 | 39 | 42.7 | 19.3 | 21 |

1. Compressive yield strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment — 1850 ° F 15 min. argon atmosphere, A. C., 1000° F 2 hr, 1000° F 2 hr, A. C.

Table 19

Shear Strength of 3/16-In. Thermold J Alloy Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | USS[1] 1000 psi | Hard[2] RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC |
| RT | | | | | | | 142.5 | 45 |
| | | | | | | | 155.0 | 45 |
| | | | | | | | 153.0 | 47 |
| Avg | | | | | | | 150.2 | 46 |
| 600 | 142.0 | 51 | 138.0 | 53 | 140.0 | 48 | 133.5 | 45 |
| | 130.0 | 45 | 135.5 | 33 | 135.0 | 46 | 142.2 | 50 |
| | 137.5 | 47 | 136.5 | 42 | 127.5 | 46 | 133.6 | 47 |
| Avg | 136.5 | 48 | 136.7 | 43 | 134.2 | 47 | 136.4 | 47 |
| 800 | 140.0 | 53 | 126.0 | 39 | 133.0 | 49 | 129.0 | 49 |
| | 128.0 | 51 | 124.0 | 45 | 135.0 | 52 | 132.0 | 51 |
| | 138.0 | 52 | 127.0 | 39 | 131.0 | 52 | 128.5 | 50 |
| Avg | 135.3 | 52 | 125.7 | 41 | 133.0 | 51 | 129.8 | 50 |
| 1000 | 113.0 | 50 | 111.0 | 45 | 110.0 | 46 | 83.3 | 36 |
| | 116.0 | 44 | 113.0 | 45 | 110.0 | 46 | 77.3 | 37 |
| | 111.5 | 50 | 111.5 | 45 | - | - | 80.0 | 36 |
| Avg | 113.5 | 48 | 111.8 | 45 | 110.0 | 46 | 80.2 | 36 |

Table 19 (continued)

Shear Strength of 3/16-In. Thermold J Alloy Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | USS[1] 1000 psi | Hard[2] RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC |
| 1100 | 89.2 | 42 | 84.7 | 40 | 53.5 | 35 | 31.5 | 19 |
| | 77.8 | 40 | 86.8 | 43 | 53.3 | 34 | 33.0 | 18 |
| | 80.4 | 41 | 86.2 | 43 | 49.5 | 35 | 32.2 | 18 |
| Avg | 82.5 | 41 | 85.9 | 42 | 52.1 | 35 | 32.2 | 18 |

1. Ultimate shear strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment —1850 °F 15 min argon atmosphere, A. C., 1000° F 2 hr, 1000° F 2 hr, A. C.

Table 20

Bearing Properties[4] of 0.062-In. Thermold J Alloy Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] | UBS[2] | Hards | BYS | UBS | Hard | BYS | UBS | Hard | BYS | UBS | Hard |
| | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N |
| RT | | | | | | | | | | 290.0 | 352.0 | 48 |
| | | | | | | | | | | 238.0 | 320.0 | 49 |
| | | | | | | | | | | 270.0 | 336.0 | 49 |
| Avg | | | | | | | | | | 266.0 | 336.0 | 49 |
| 600 | 285.0 | 318.0 | 53 | 253.0 | 321.0 | 52 | 268.0 | 312.0 | 53 | 264.0 | 303.0 | 51 |
| | 285.0 | 324.0 | 54 | 265.0 | 314.0 | 53 | 263.5 | 310.0 | 50 | 246.0 | 306.0 | 51 |
| | 282.0 | 318.0 | 52 | 257.0 | 321.0 | 51 | 275.0 | 310.0 | 50 | 271.0 | 316.0 | 48 |
| Avg | 284.0 | 320.0 | 53 | 258.3 | 318.7 | 52 | 268.8 | 310.7 | 51 | 260.3 | 308.3 | 50 |
| 800 | 247.0 | 293.0 | 50 | 248.0 | 300.0 | 50 | 251.5 | 295.0 | 51 | 269.0 | 300.0 | 51 |
| | 269.5 | 292.0 | 51 | 254.5 | 296.0 | 49 | 251.0 | 295.0 | 49 | 235.0 | 278.0 | 52 |
| | 255.0 | 293.0 | 49 | 254.0 | 295.0 | 50 | 251.0 | 294.0 | 50 | 259.0 | 295.0 | 52 |
| Avg | 257.2 | 292.7 | 50 | 252.2 | 297.0 | 50 | 251.2 | 294.7 | 50 | 254.3 | 291.0 | 52 |
| 1000 | — | 238.0 | 53 | 206.0 | 242.5 | 49 | 208.0 | 227.0 | 48 | 133.5 | 176.0 | 44 |
| | 212.0 | 247.0 | 49 | 209.0 | 237.2 | 49 | 211.0 | 232.5 | 47 | 134.8 | 169.8 | 44 |
| | 203.0 | 241.0 | 50 | 195.5 | 233.0 | 48 | 211.0 | 228.5 | 47 | 134.8 | 172.6 | 43 |
| Avg | 207.5 | 242.0 | 51 | 203.5 | 237.6 | 49 | 210.0 | 229.3 | 47 | 134.4 | 172.8 | 44 |

Table 20 (continued)

Bearing Properties[4] of 0.062-In. Thermold J Alloy Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp ° F | BYS[1] 1000 psi | UBS[2] 1000 psi | Hard[3] R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N |
| 1100 | 168.4 | 185.0 | 47 | 155.0 | 162.5 | 44 | 97.5 | 109.5 | 40 | 61.3 | 65.2 | 21 |
| | 169.0 | 185.0 | 47 | – | – | – | 88.0 | 94.0 | 40 | 57.6 | 63.0 | 21 |
| | 157.8 | 185.0 | 47 | – | – | – | 88.3 | 96.0 | 40 | – | – | – |
| Avg | 165.0 | 185.0 | 47 | 155.0 | 162.5 | 44 | 91.3 | 99.8 | 40 | 59.4 | 64.1 | 21 |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge-distance to hole-diameter ratio 1.5
5. Heat treatment —1850 ° F 15 min argon atmosphere, A. C., 1000° F 2 hr, 1000° F 2 hr, A. C.

Table 21

Bearing Properties[4] of 0.062-In. Thermold J Alloy Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr / Temp °F | 1/2 BYS[1] (1000 psi) | 1/2 UBS[2] (1000 psi) | 1/2 Hard[3] R45N | 10 BYS (1000 psi) | 10 UBS (1000 psi) | 10 Hard R45N | 100 BYS (1000 psi) | 100 UBS (1000 psi) | 100 Hard R45N | 1000 BYS (1000 psi) | 1000 UBS (1000 psi) | 1000 Hard R45N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RT | | | | | | | | | | – | 492.0 | 49 |
| | | | | | | | | | | 360.0 | 465.0 | 49 |
| | | | | | | | | | | 347.0 | 492.0 | 49 |
| | | | | | | | | | | 300.0 | 447.0 | 49 |
| Avg | | | | | | | | | | 335.7 | 474.0 | 49 |
| 600 | 358.0 | 428.0 | 45 | 323.0 | 429.0 | 53 | 330.0 | 430.0 | 49 | 305.0 | 426.0 | 52 |
| | 311.0 | 429.0 | 45 | 318.0 | 436.0 | 51 | 324.0 | 430.0 | 49 | 346.0 | 442.0 | 50 |
| | 323.0 | 444.0 | 47 | 314.5 | 442.5 | 52 | 312.0 | 430.0 | 49 | 306.0 | 417.0 | 52 |
| Avg | 330.3 | 433.7 | 46 | 318.5 | 435.8 | 52 | 322.0 | 430.0 | 49 | 319.0 | 428.3 | 51 |
| 800 | 293.0 | 393.0 | 50 | 288.0 | 396.0 | 48 | 294.0 | 388.0 | 50 | 291.0 | 396.0 | 53 |
| | 291.0 | 388.2 | 53 | 295.5 | 394.0 | 50 | 341.0 | 401.0 | 51 | 268.0 | 380.0 | 54 |
| | 305.0 | 390.0 | 52 | 292.5 | 398.0 | 48 | 310.0 | 402.5 | 49 | 322.0 | 381.0 | 52 |
| Avg | 296.3 | 390.4 | 52 | 292.0 | 396.0 | 49 | 315.0 | 397.2 | 50 | 293.7 | 385.7 | 53 |
| 1000 | 240.0 | 317.5 | 52 | 247.0 | 312.0 | 49 | 206.0 | 290.0 | 51 | 147.0 | 217.5 | 43 |
| | 211.0 | 312.0 | 51 | 241.0 | 312.0 | 51 | 213.5 | 282.0 | 51 | 133.5 | 212.0 | 43 |
| | 243.0 | 314.0 | 52 | 228.0 | 301.0 | 50 | 209.0 | 288.0 | 50 | 153.0 | 212.0 | 43 |
| Avg | 231.3 | 314.5 | 52 | 238.7 | 303.3 | 50 | 209.5 | 286.7 | 51 | 144.5 | 213.8 | 43 |

Table 21 (continued)

Bearing Properties[4] of 0.062-In. Thermold J Alloy Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] 1000 psi | UBS[2] 1000 psi | Hard[3] R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N |
| 1100 | 166.4 | 194.0 | 42 | 191.0 | 215.0 | 44 | 99.0 | 132.0 | 37 | 73.7 | 90.3 | 19 |
| | 174.0 | 202.5 | 41 | 169.0 | 212.0 | 46 | 104.3 | 130.5 | 39 | 75.5 | 92.6 | 20 |
| | — | — | — | 172.2 | 217.0 | 46 | 117.8 | 137.8 | 38 | 73.6 | 89.4 | 19 |
| Avg | 170.2 | 198.2 | 42 | 177.4 | 214.7 | 45 | 107.0 | 133.4 | 38 | 74.3 | 90.8 | 19 |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge-distance to hole-diameter ratio 2.0.
5. Heat treatment – 1850° F 15 min argon atmosphere, A. C., 1000° F 2 hr, 1000° F 2 hr, A. C.

## 10.4 Type 420 Stainless Steel Sheet, Quenched and Tempered

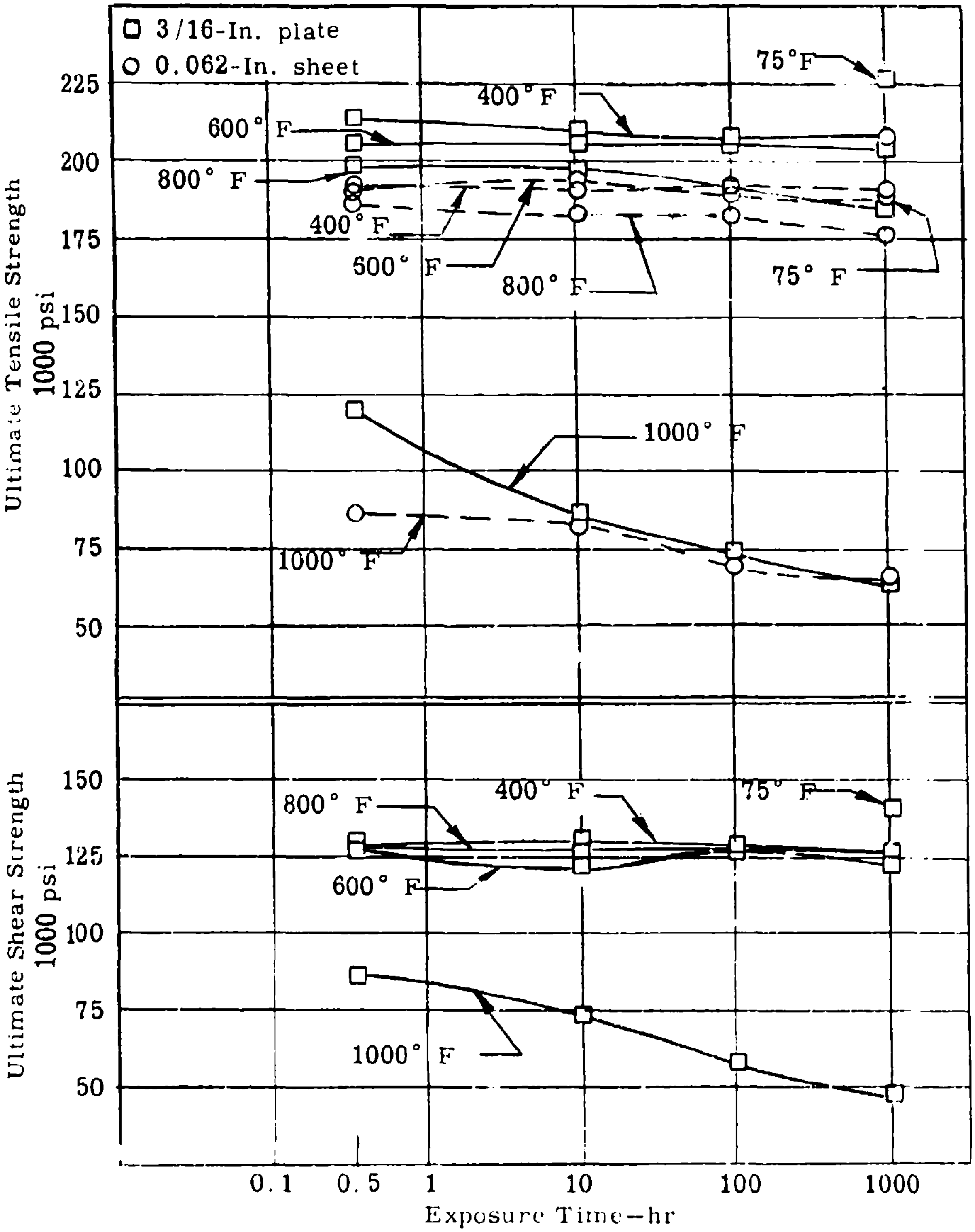


Fig. 79. Effect of exposure time on the ultimate tensile strength and ultimate shear strength of quenched and tempered Type 420 stainless steel at different temperatures.

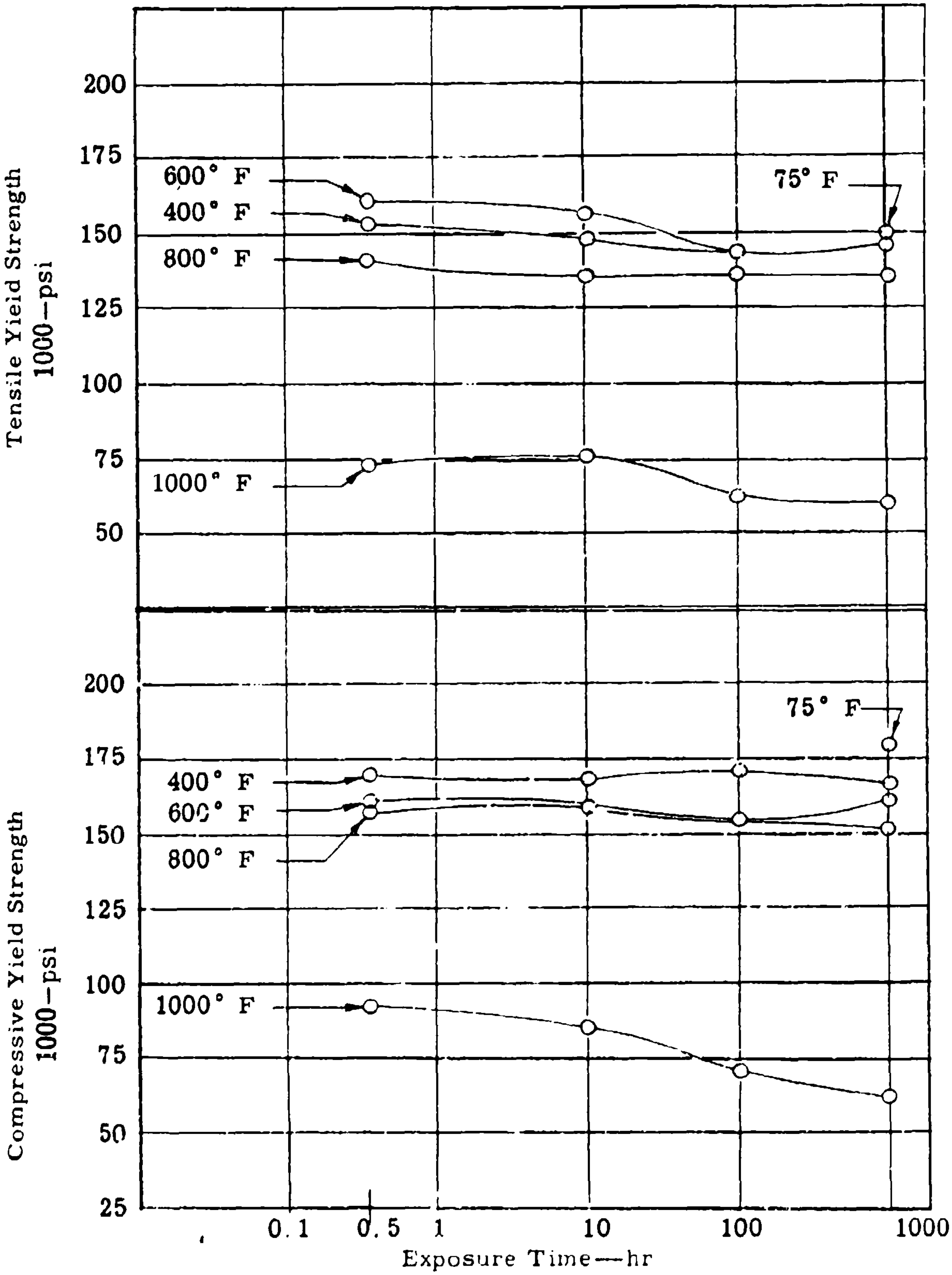


Fig. 80. Effect of exposure time on the tensile and compressive yield strength of quenched and tempered Type 420 stainless steel sheet at different temperatures

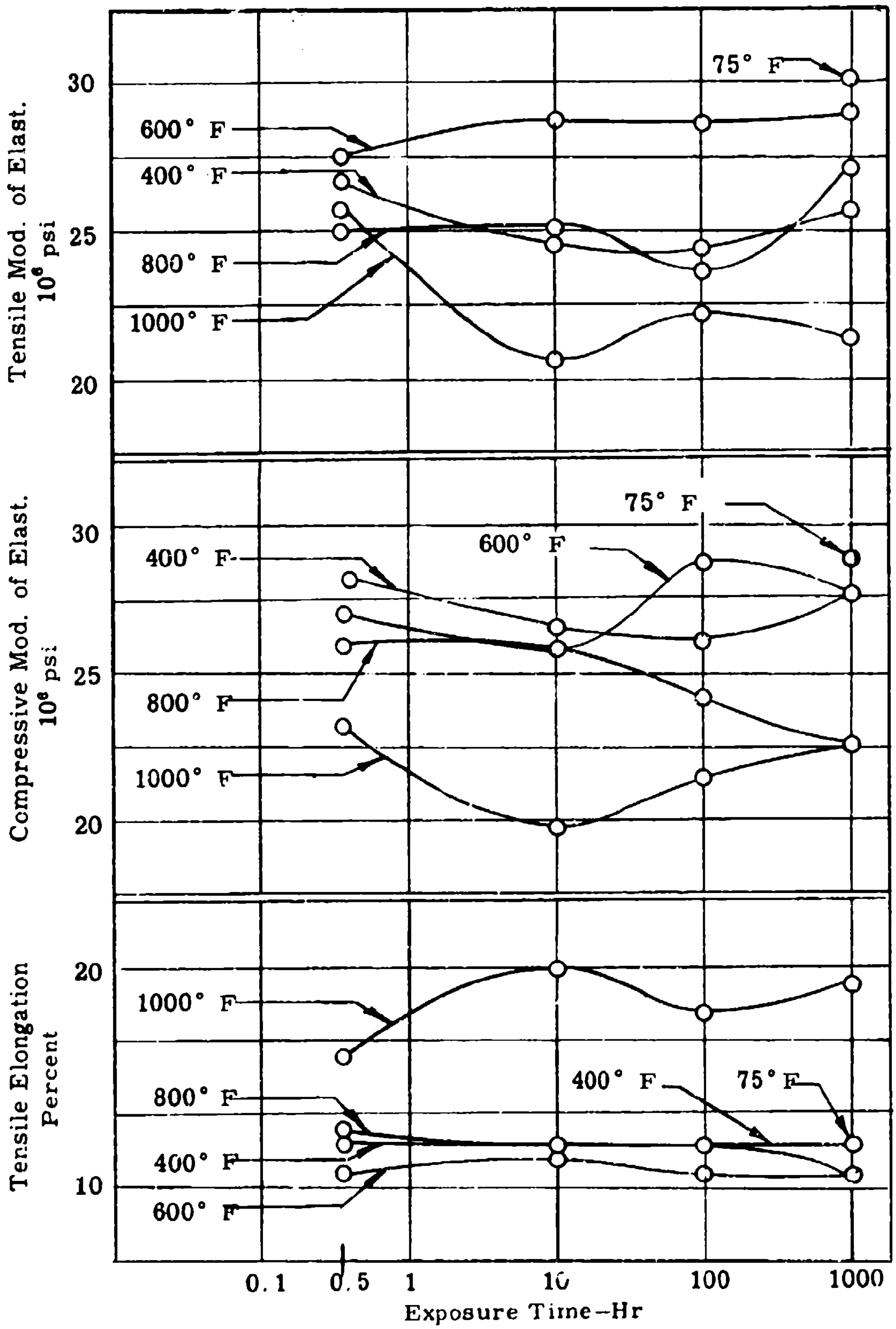


Fig. 81. Effect of exposure time on the tensile and compressive moduli of elasticity and percent elongation of quenched and tempered Type 420 stainless steel sheet at different temperatures.

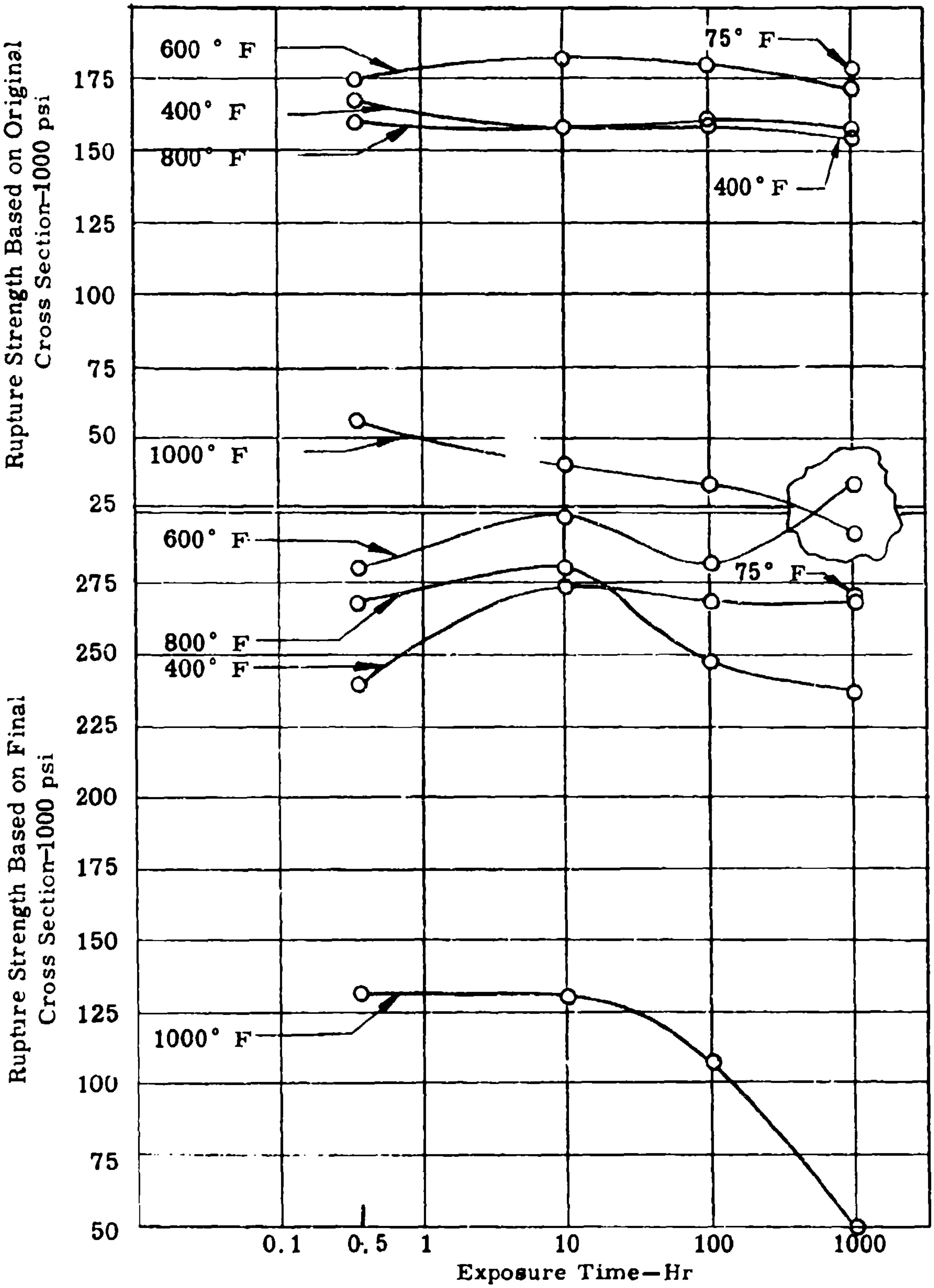


Fig. 87. Effect of exposure time on the tensile rupture strength of quenched and tempered Type 420 stainless steel sheet at different temperatures.

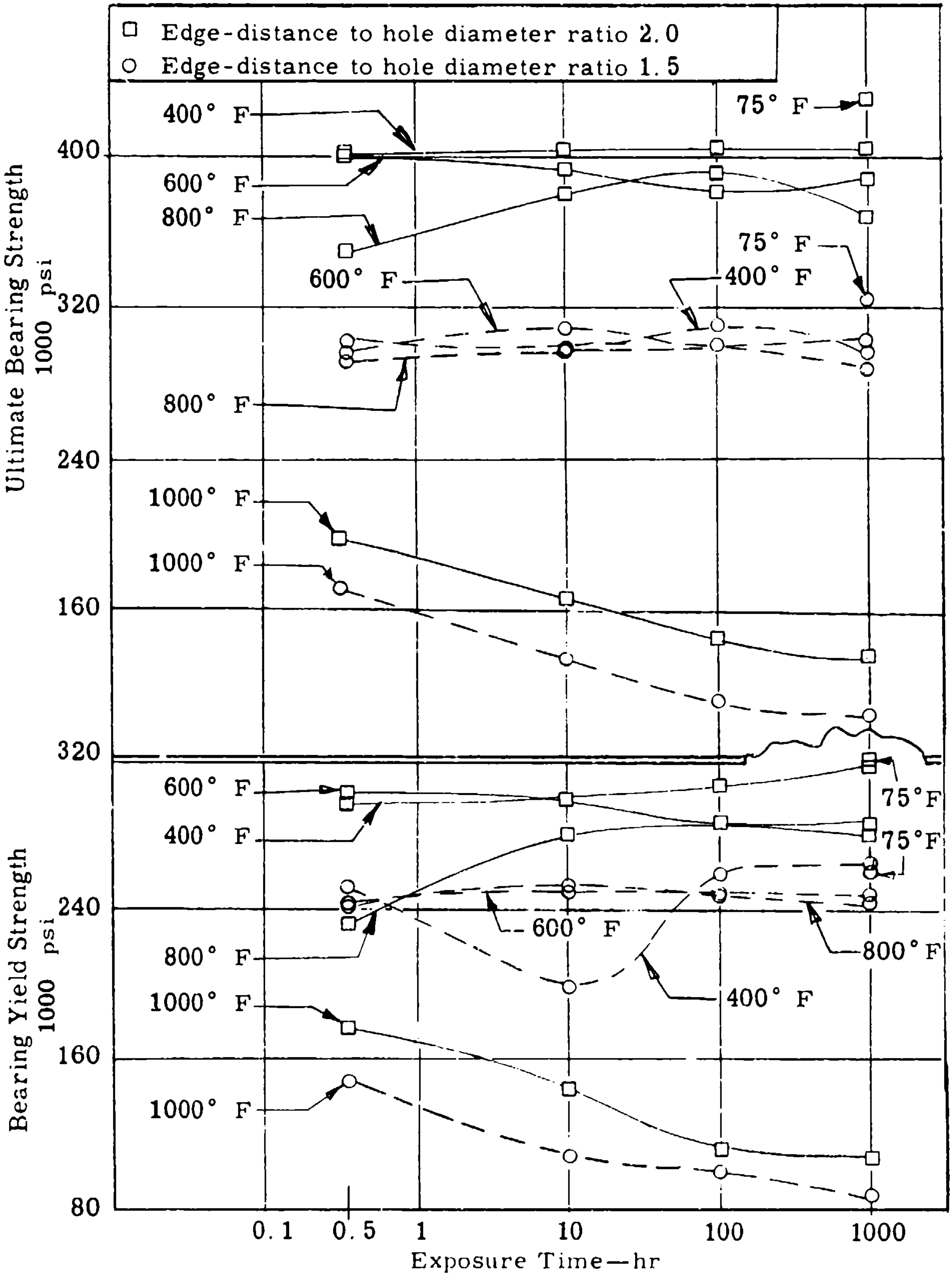


Fig. 83. Effect of exposure time on the bearing ultimate and yield strengths of quenched and tempered Type 420 stainless steel sheet at different temperatures

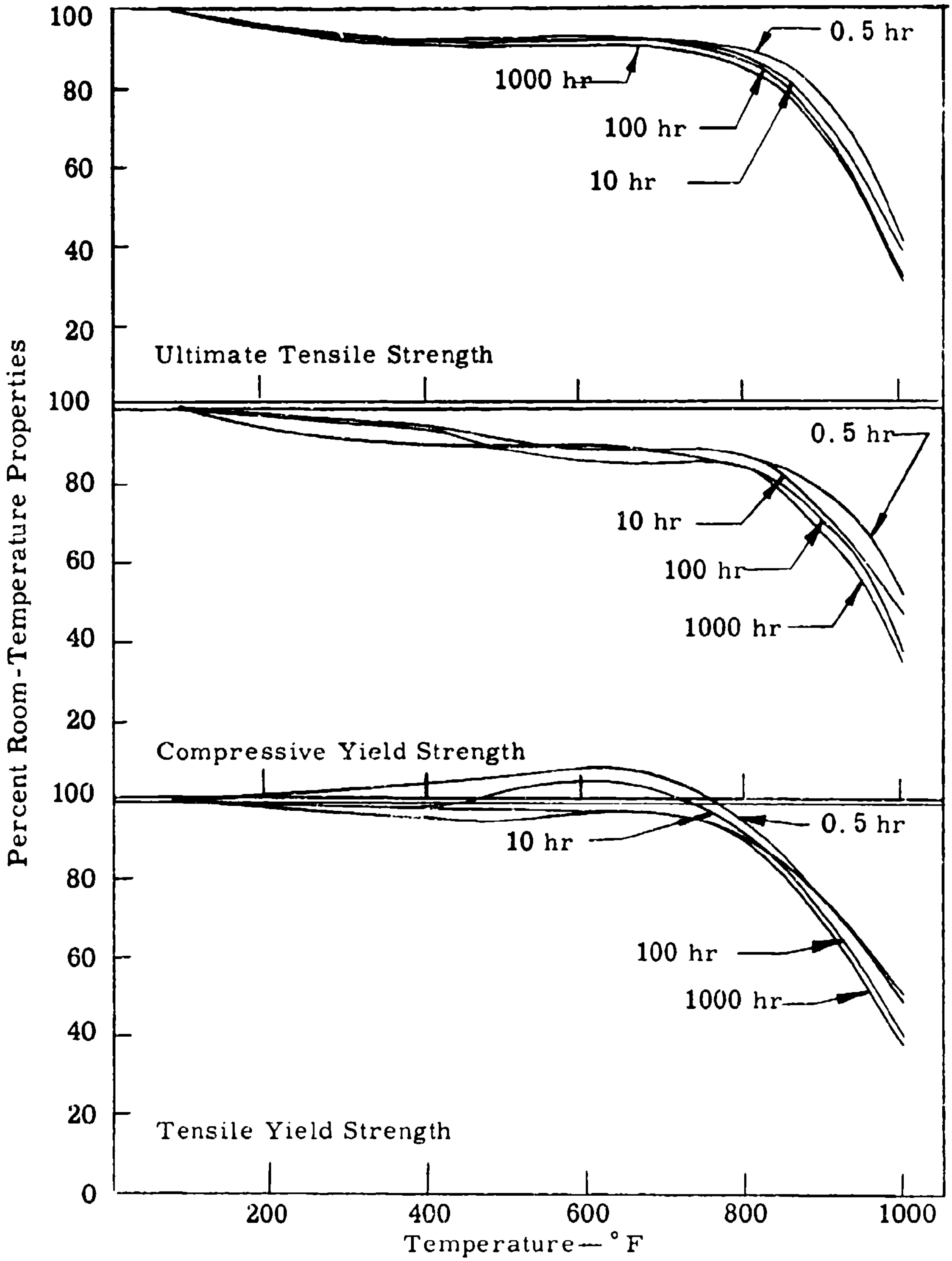


Fig. 84. Elevated-temperature strength properties as percent room-temperature properties for quenched and tempered Type 420 stainless steel sheet at different exposure times.

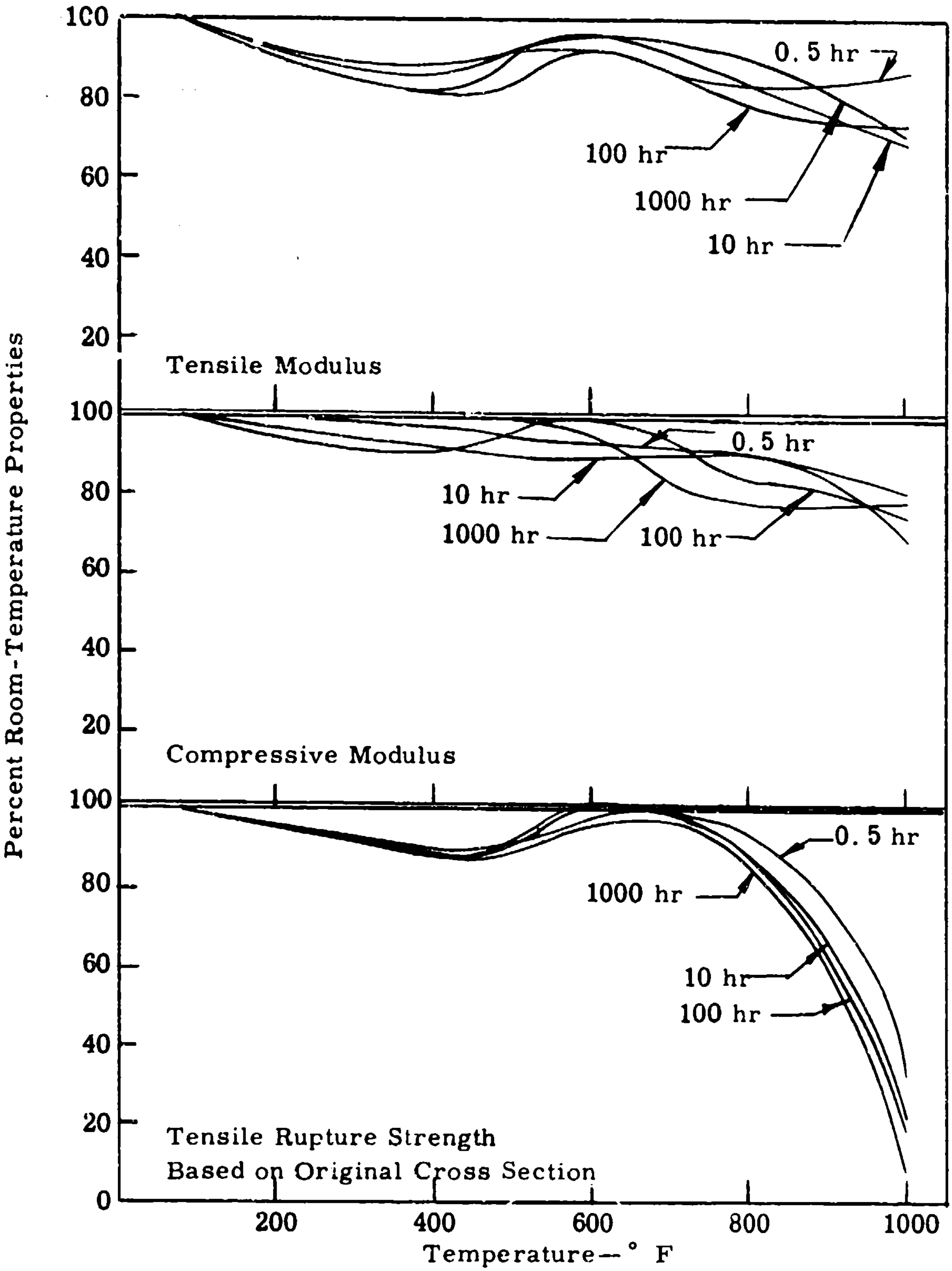


Fig. 85. Elevated-temperature properties as percent room-temperature properties for quenched and tempered Type 420 stainless steel sheet at different exposure times.

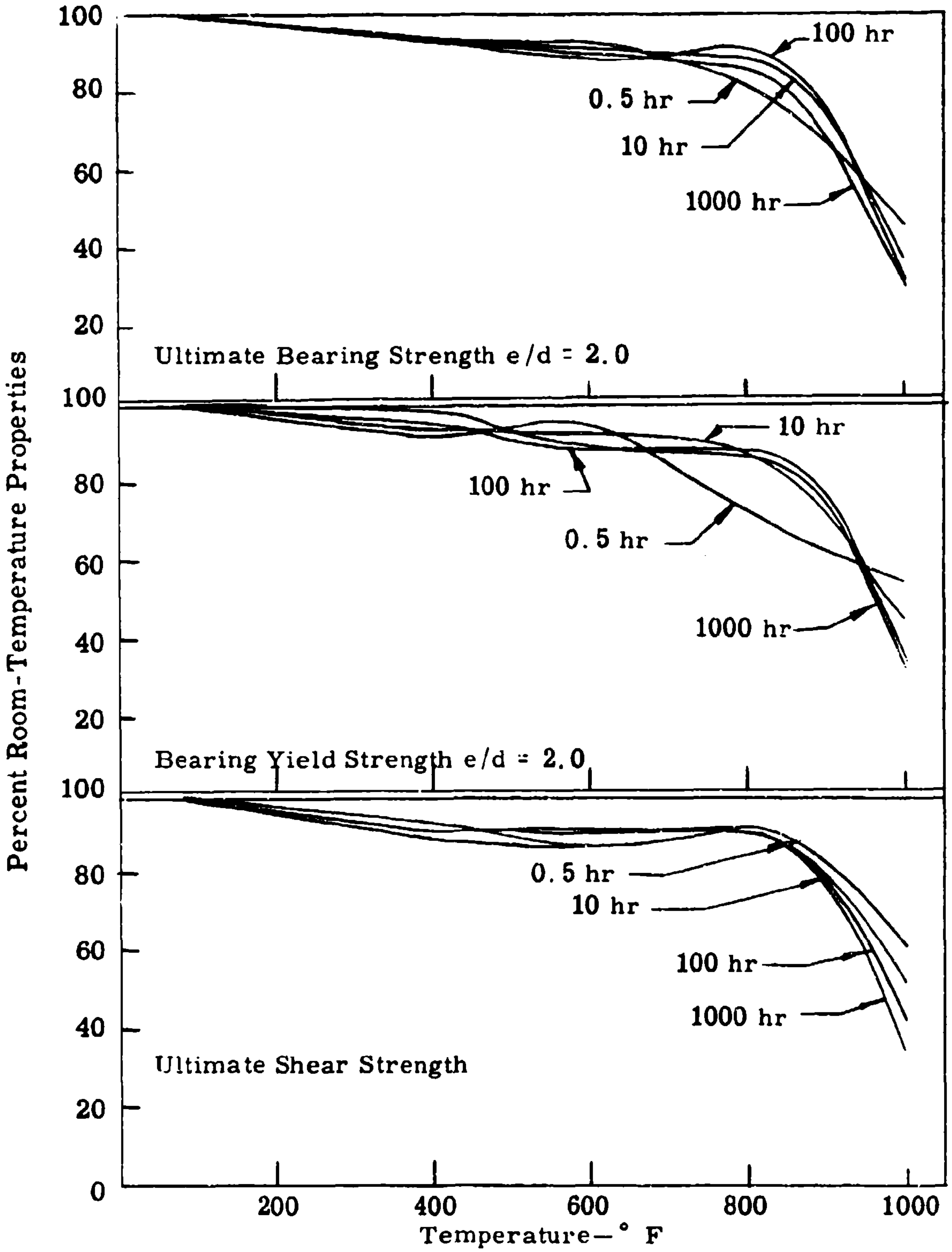


Fig. 86. Elevated-temperature strength properties as percent room-temperature properties for quenched and tempered Type 420 stainless steel sheet at different exposure times.

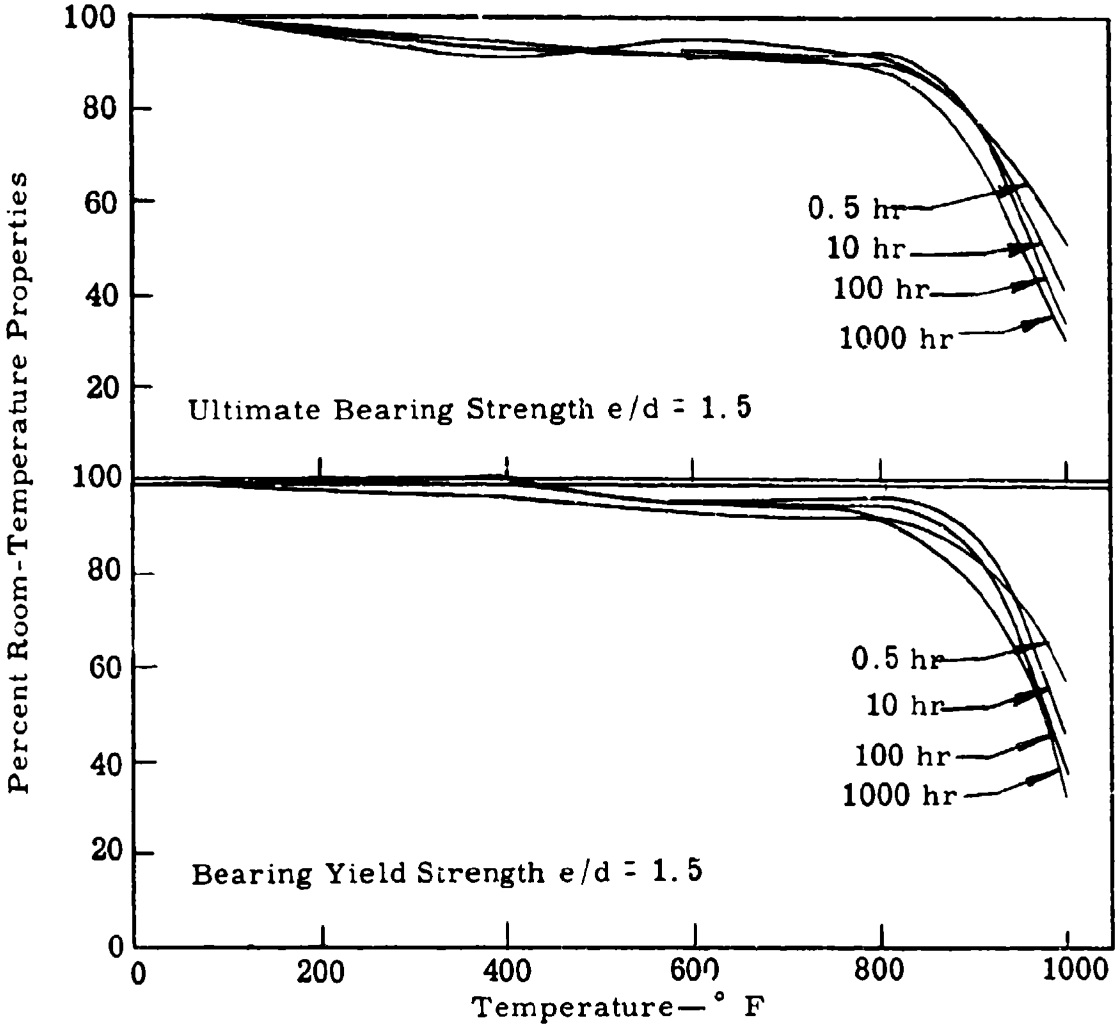


Fig. 87. Elevated-temperature strength properties as percent room-temperature properties for quenched and tempered Type 420 stainless steel sheet at different exposure times.

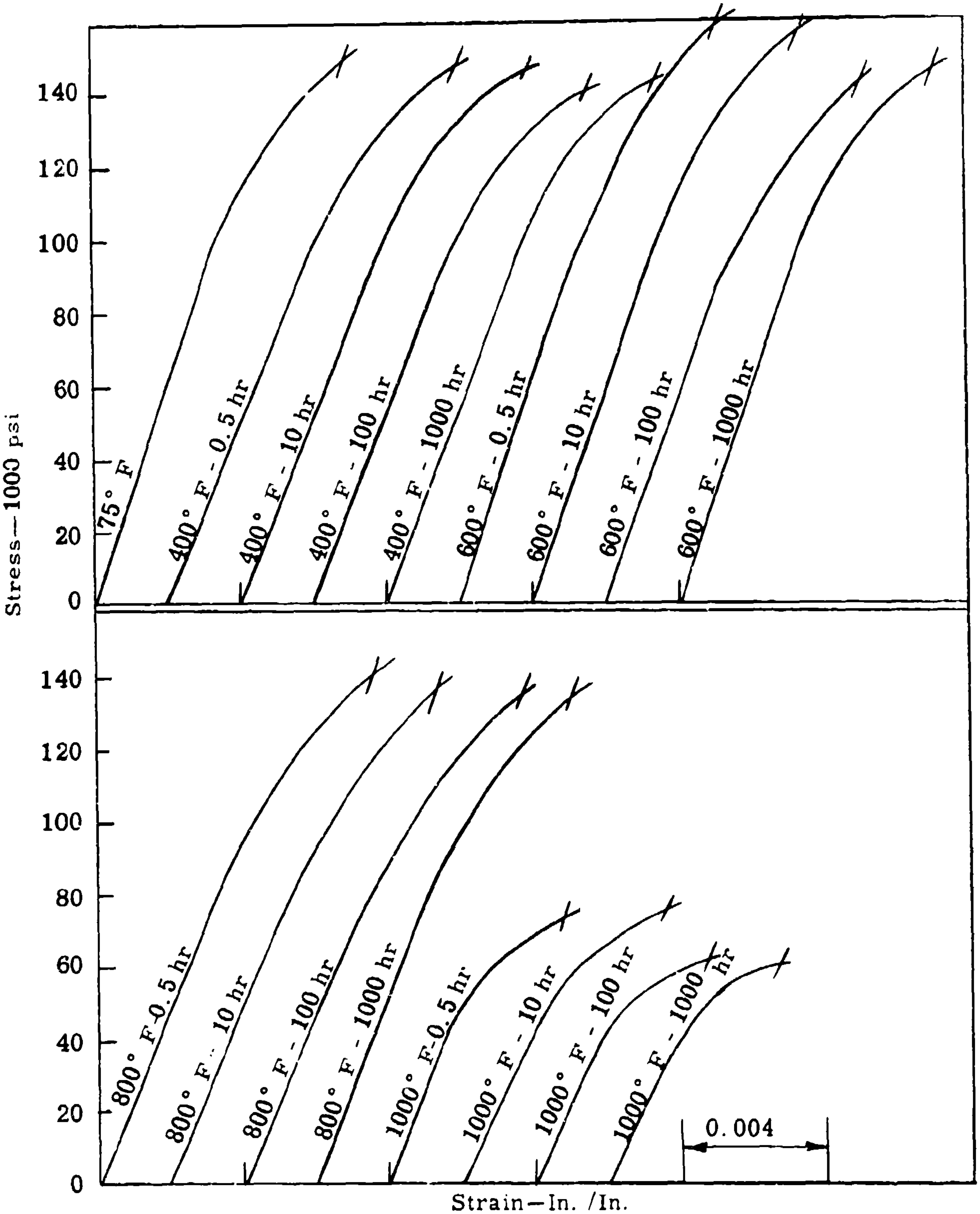


Fig. 88. Tensile stress-strain curves for quenched and tempered Type 420 stainless steel sheet at various temperatures and exposure times.

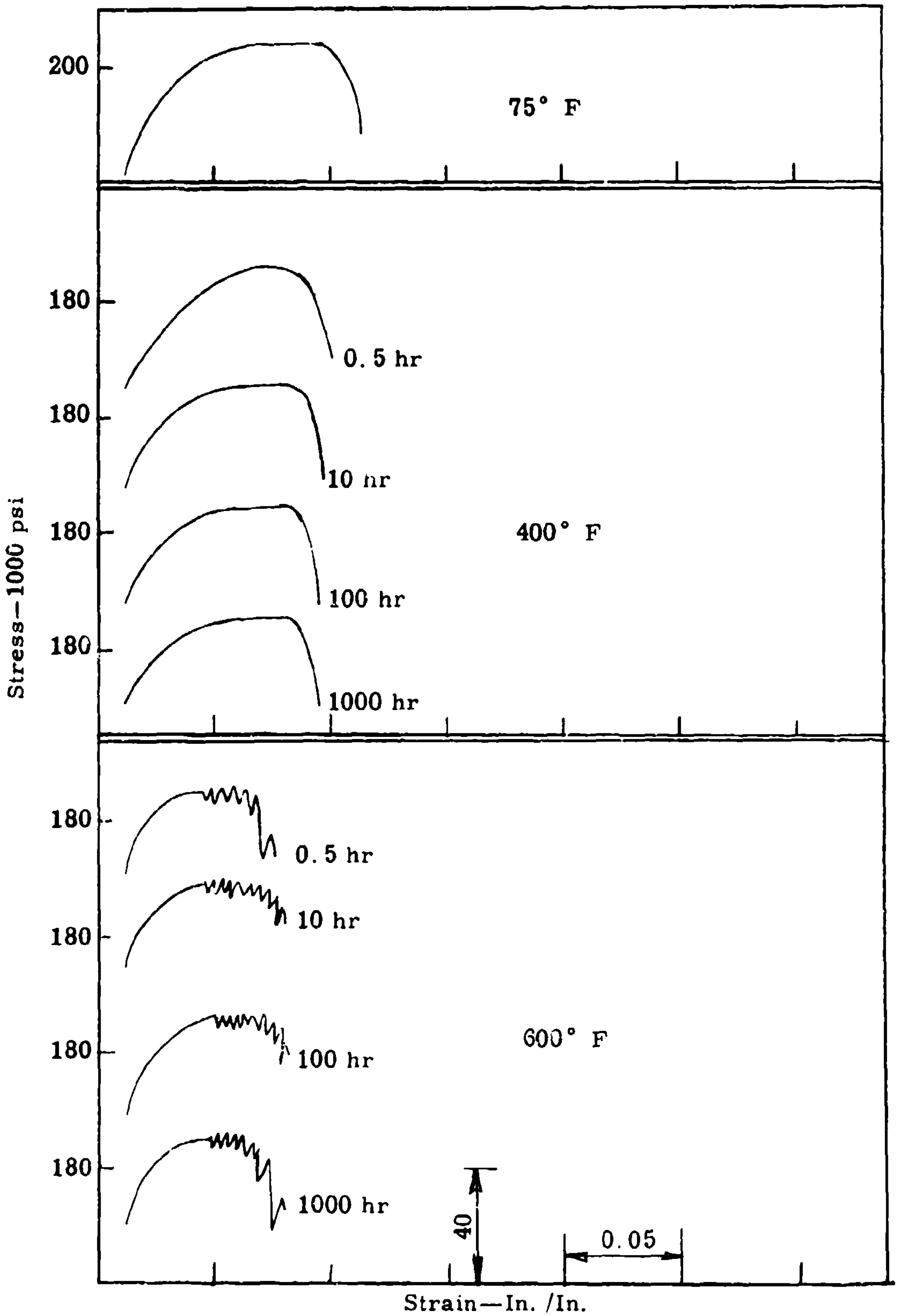


Fig. 89. Tensile postyield stress-strain curves for quenched and tempered Type 420 stainless steel sheet at various temperatures and exposure times

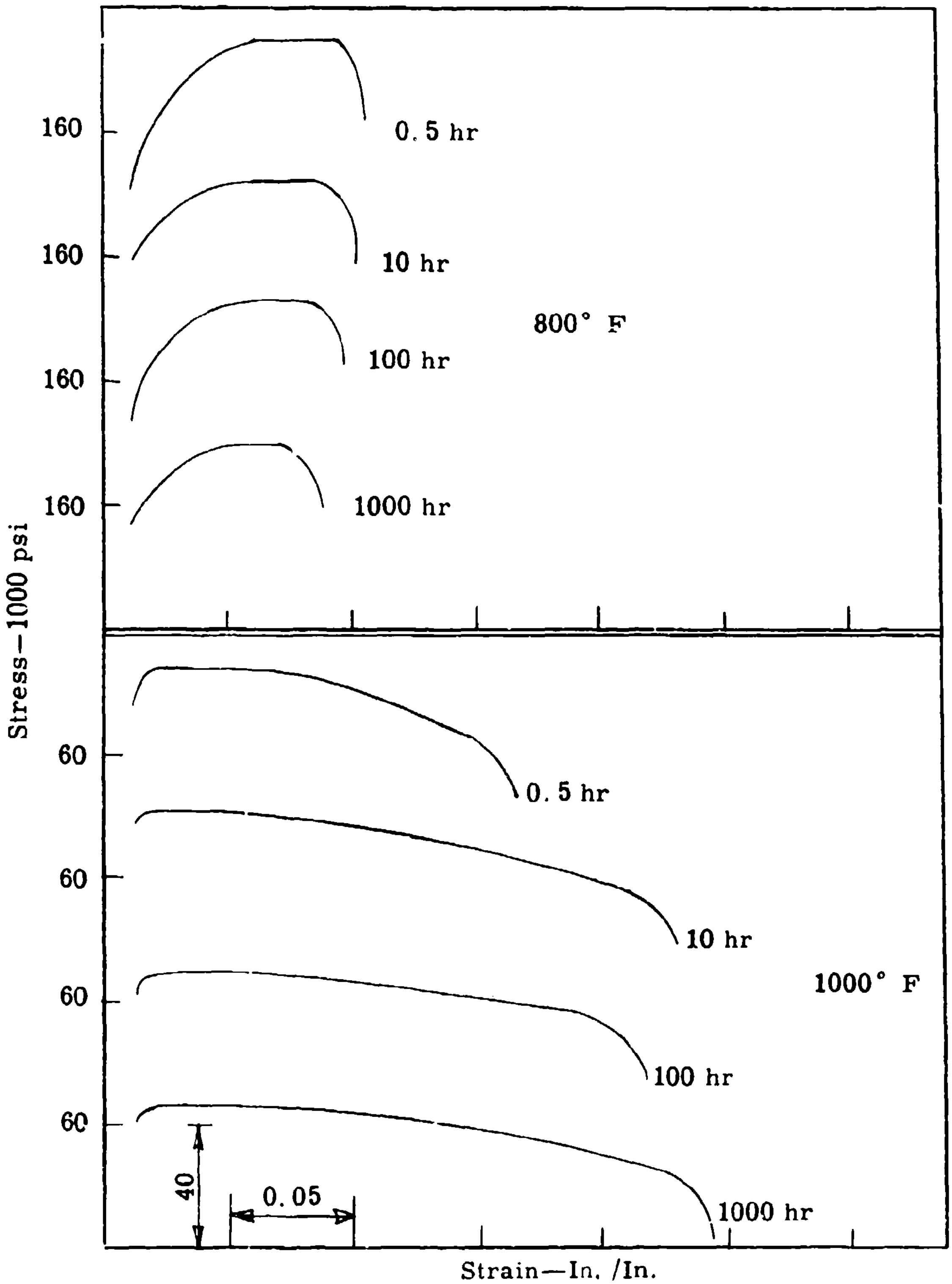


Fig. 90. Tensile postyield stress-strain curves for quenched and tempered Type 420 stainless-steel sheet at various temperatures and exposure times.

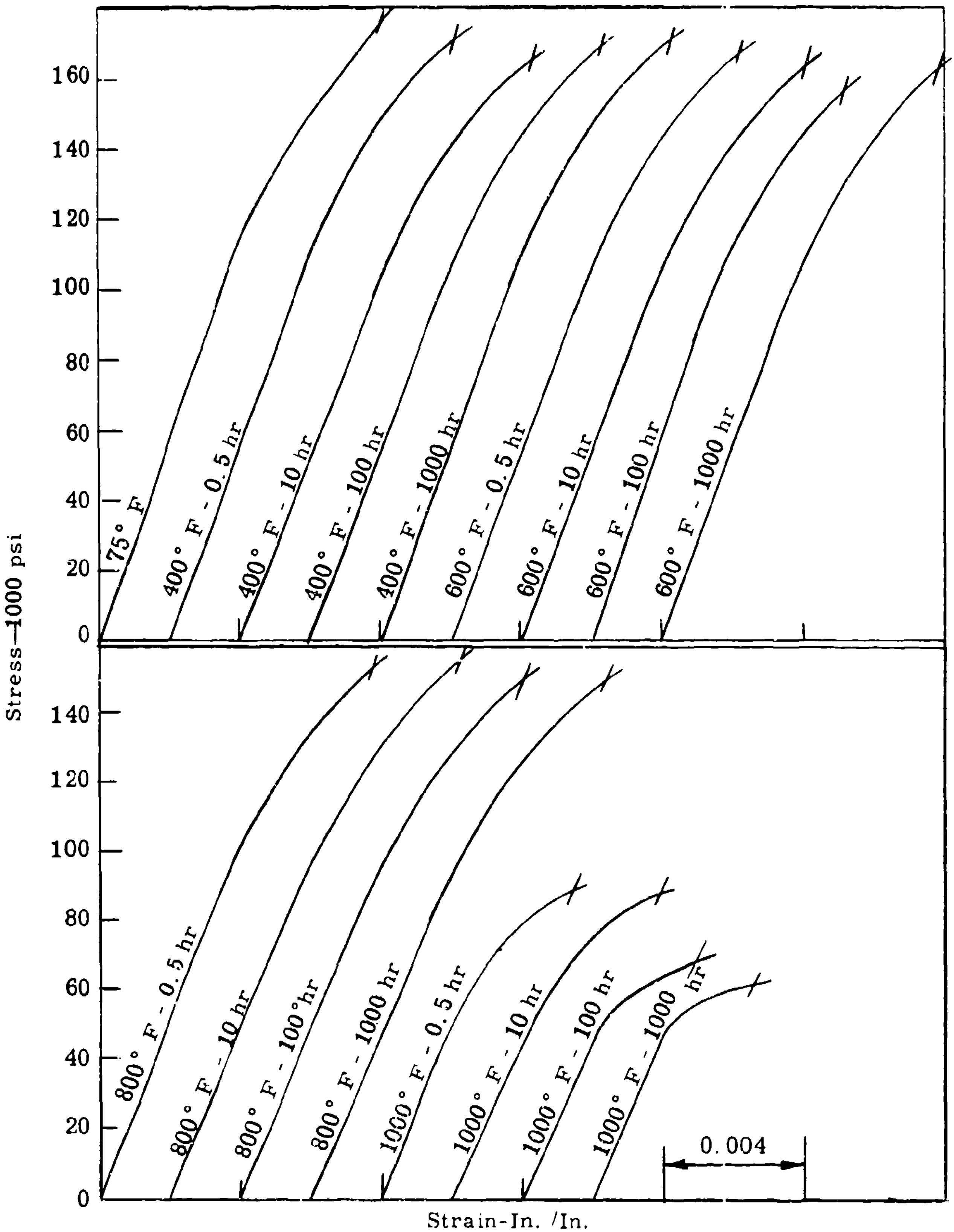


Fig. 91. Compressive stress-strain curves for quenched and tempered Type 420 stainless steel sheet at various temperatures and exposure times.

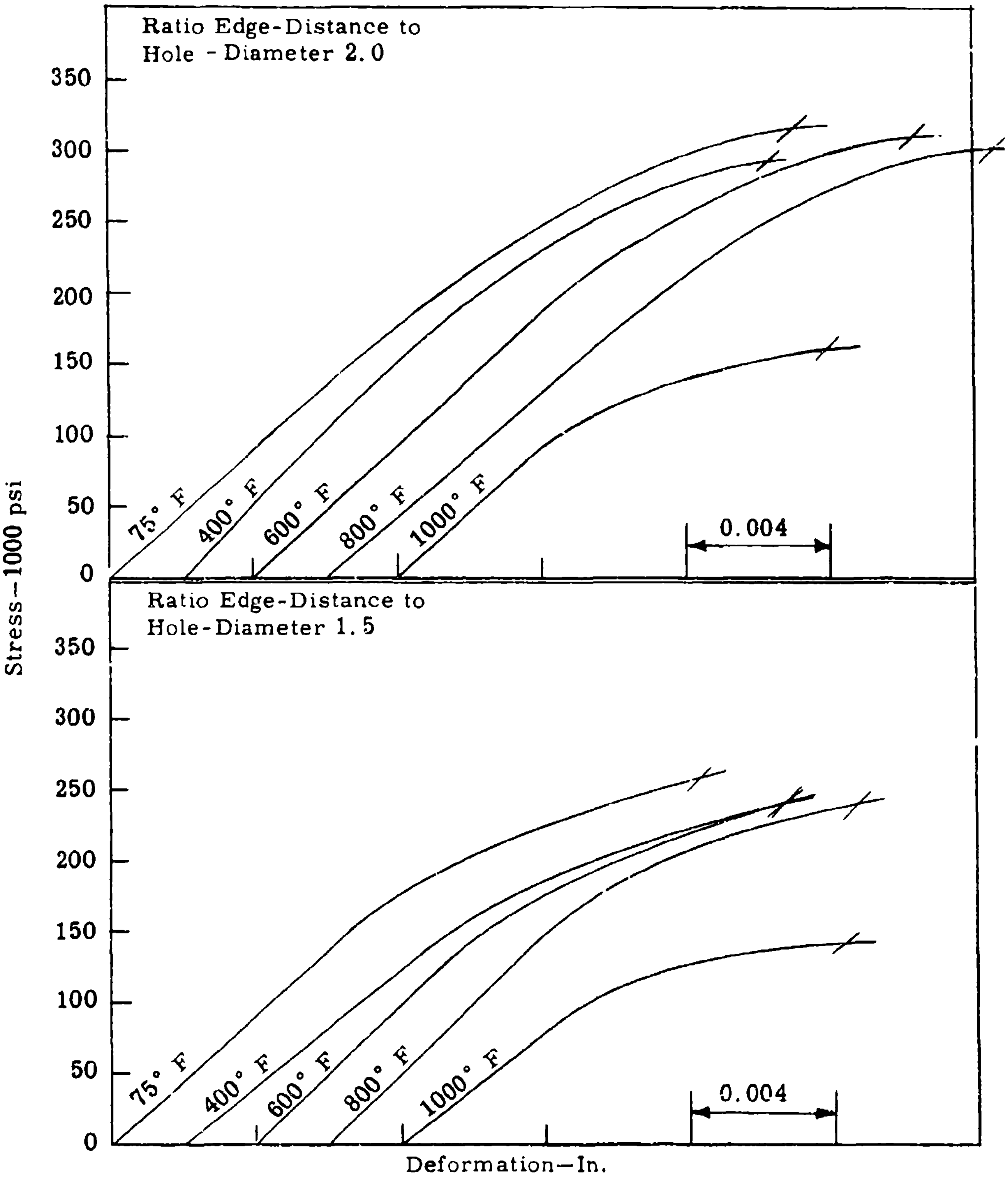


Fig. 92. Bearing stress-deformation curves for quenched and tempered Type 420 stainless steel sheet at various temperatures and one-half-hour exposure time.

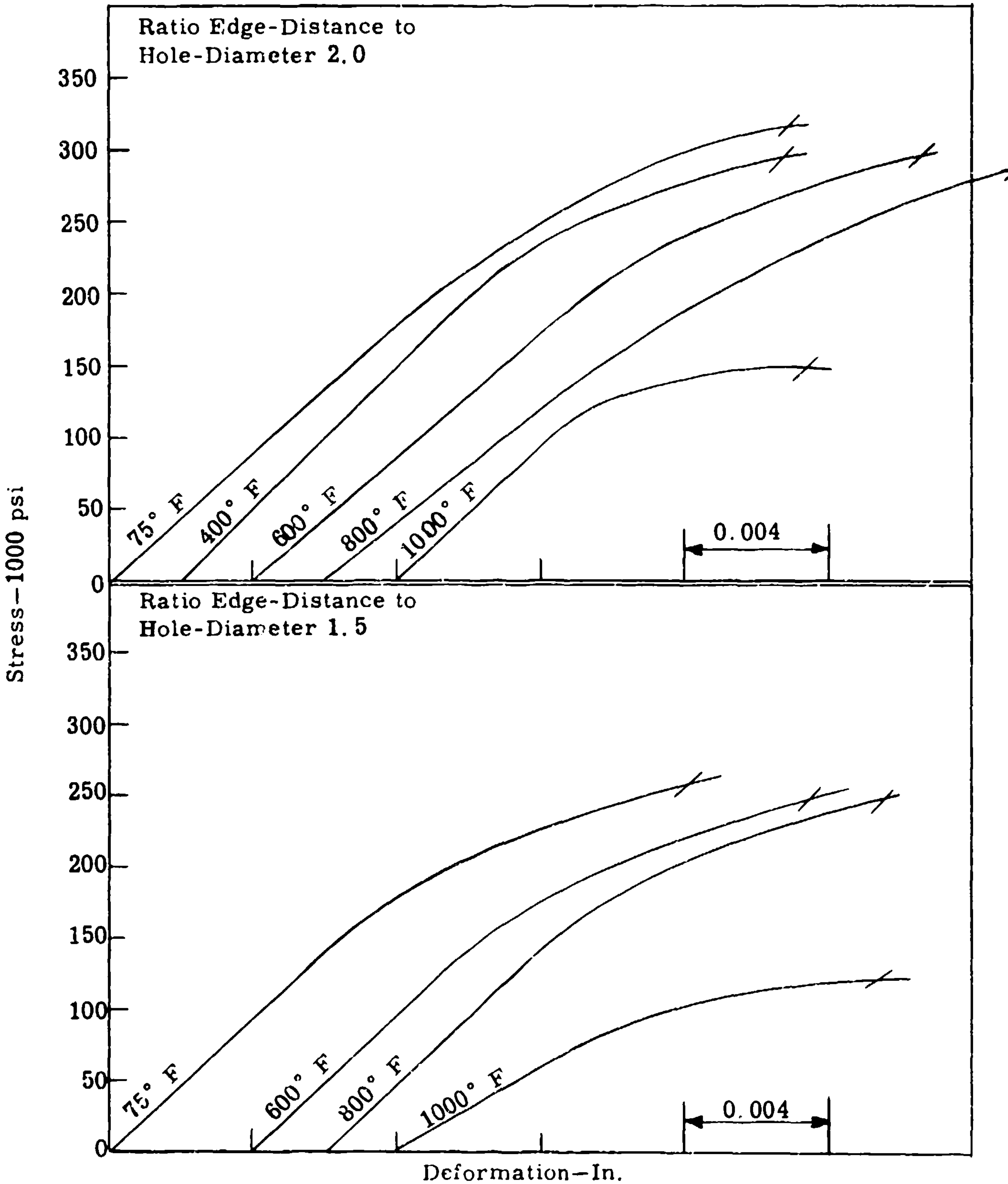


Fig. 93. Bearing stress-deformation curves for quenched and tempered Type 420 stainless steel sheet at various temperatures and ten-hour exposure time.

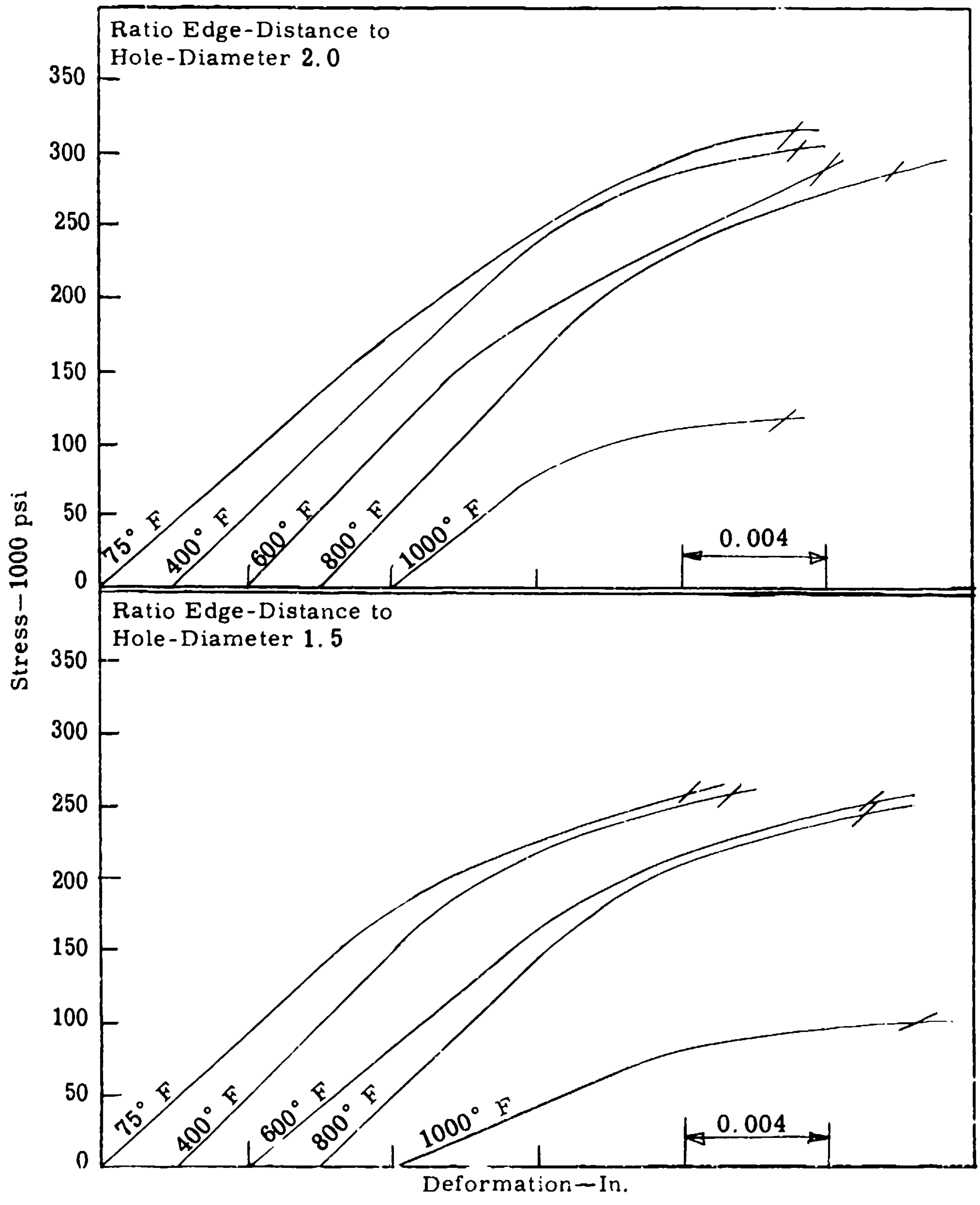


Fig. 94. Bearing stress-deformation curves for quenched and tempered Type 420 stainless steel sheet at various temperatures and one-hundred-hour exposure time.

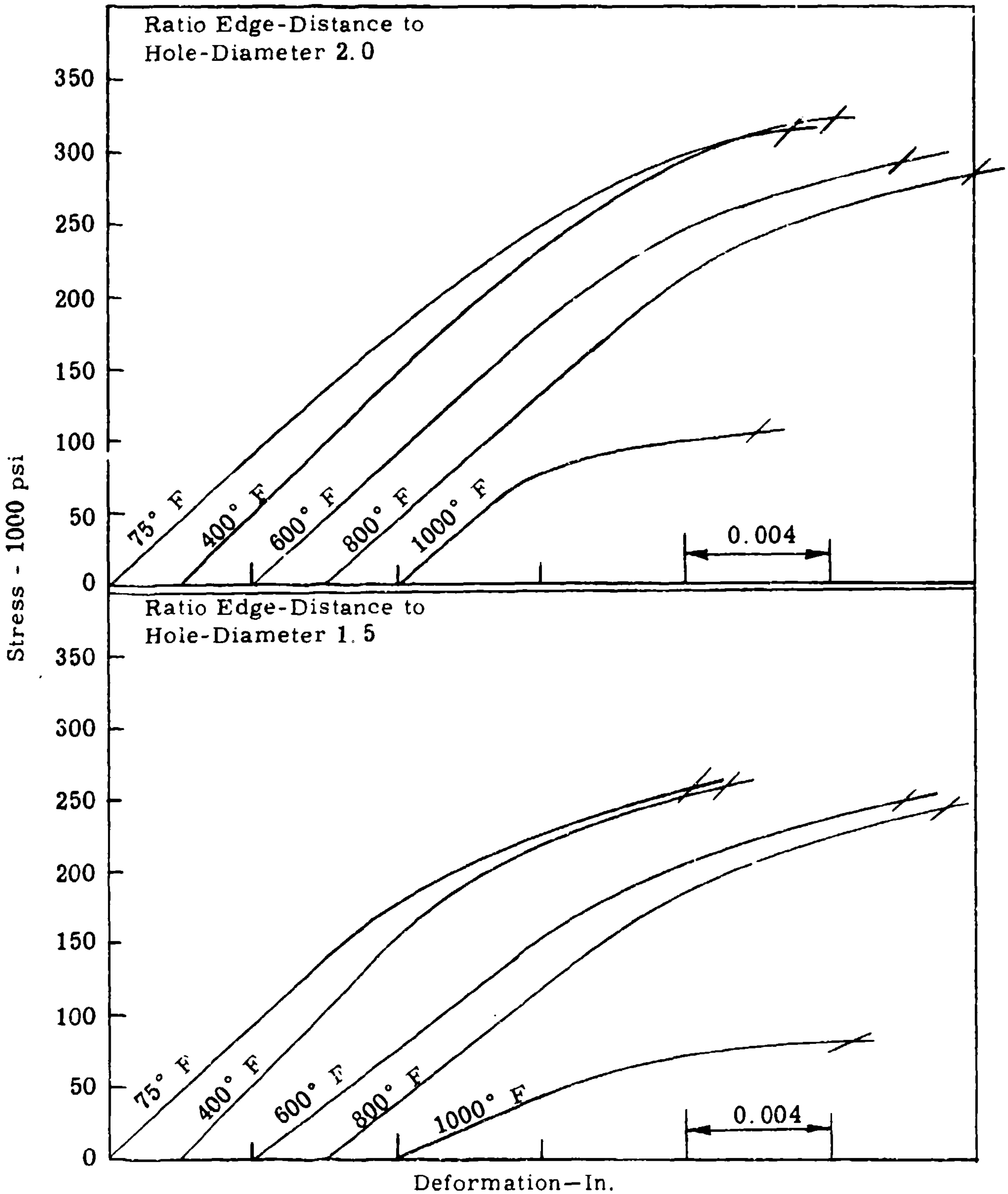


Fig. 95. Bearing stress-deformation curves for quenched and tempered Type 420 stainless steel sheet at various temperatures and one-thousand-hour exposure time.

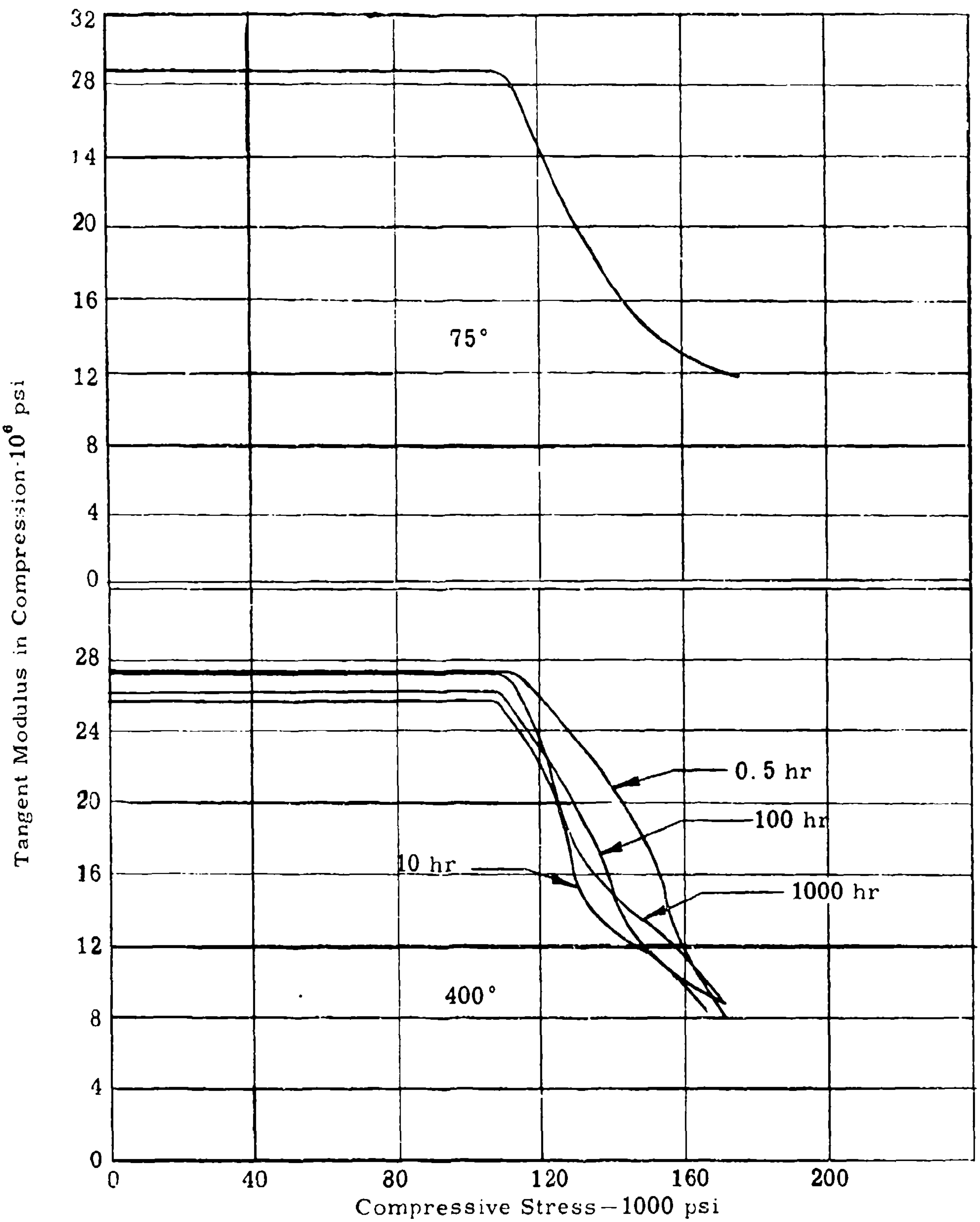


Fig. 96. Tangent-modulus vs. compressive-stress curves for quenched and tempered Type 420 stainless steel sheet at 75° F and 400° F and different exposure times.

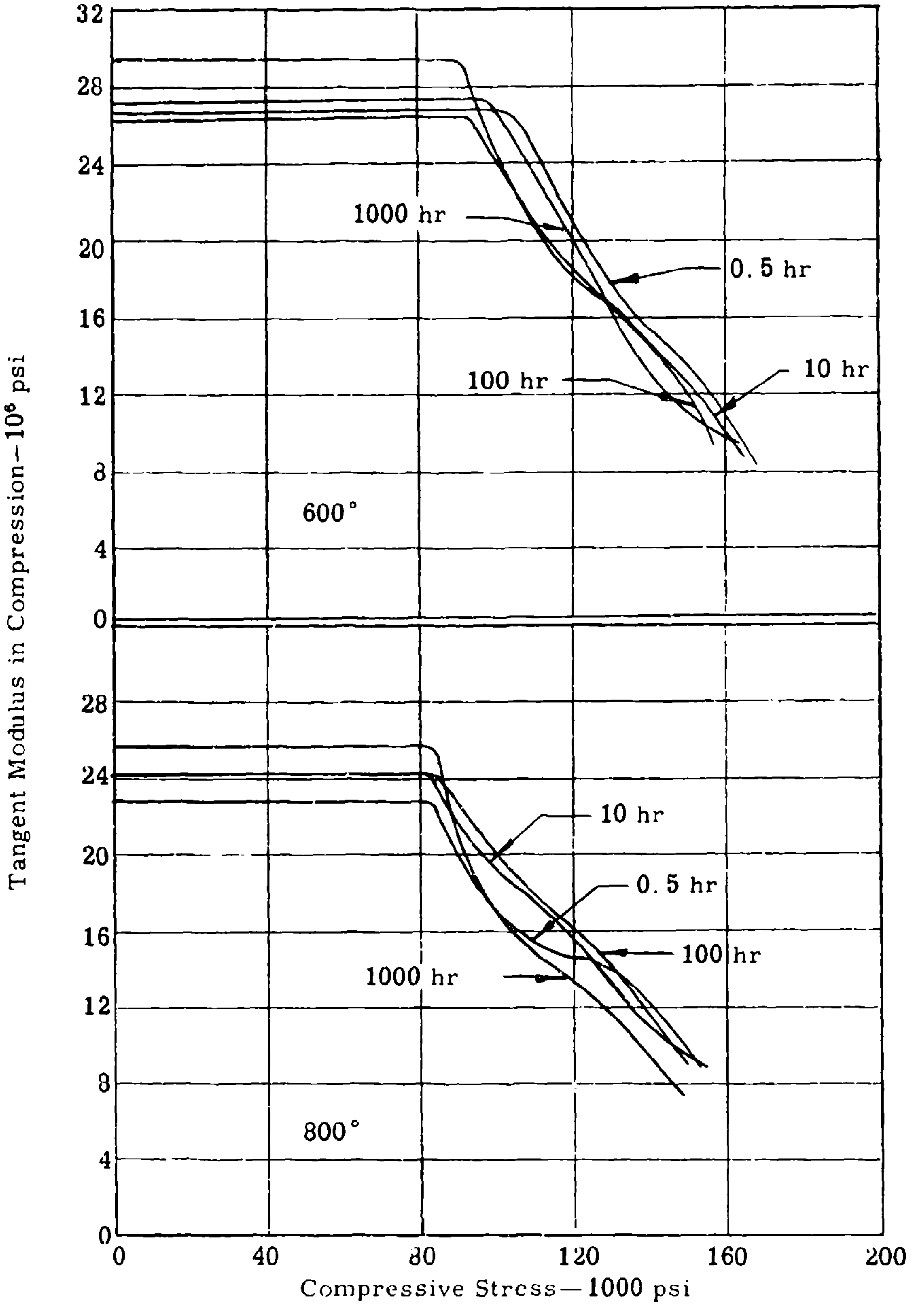


Fig. 97. Tangent-modulus vs. compressive-stress curves for quenched and tempered Type 420 stainless steel sheet at 600° F and 800° F and different exposure times.

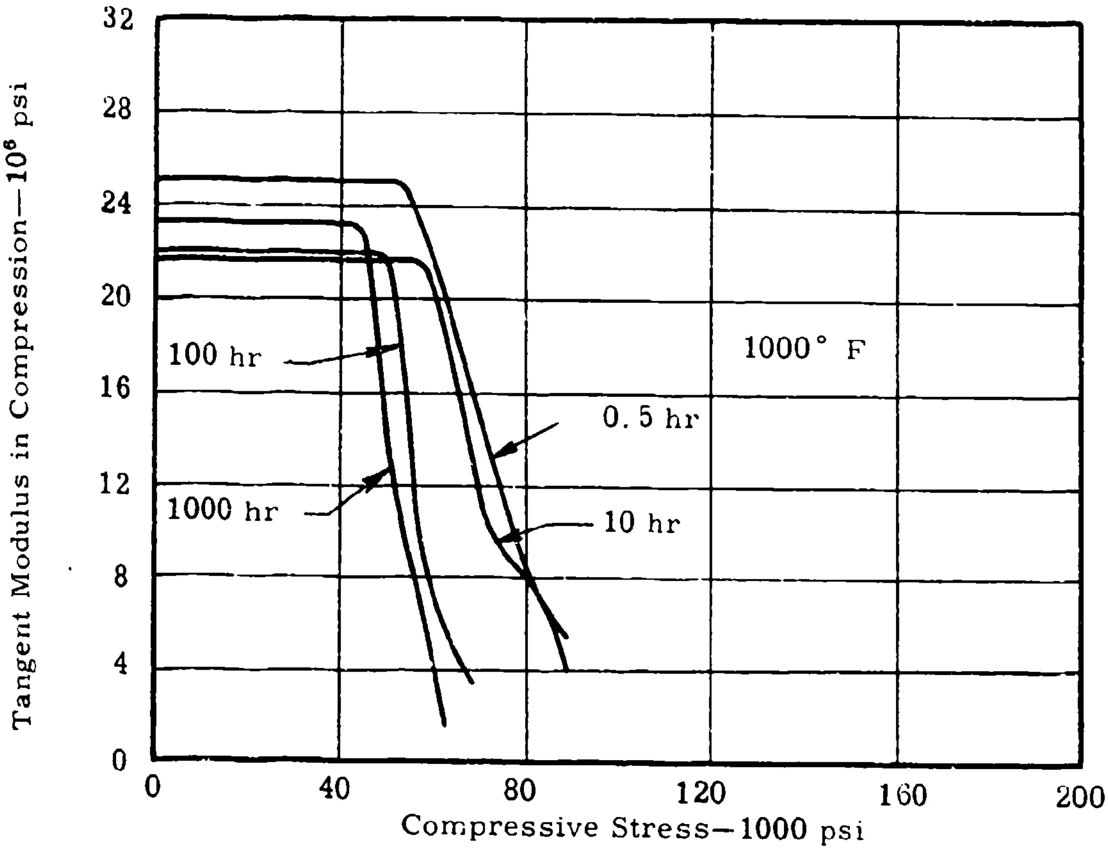


Fig. 98. Tangent-modulus vs. compressive-stress curves for quenched and tempered Type 420 stainless steel sheet at 1000° F and different exposure times.

Table 22

Tensile Properties of 0.062-In. Type 420 Stainless Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| RT | | 151.1 | 208.0 | 30.0 | 8 | 51 | 178.2 | 299.0 |
| | | 147.0 | 208.0 | 30.3 | 8 | 51 | 174.2 | 274.0 |
| | | 150.0 | 207.0 | 30.3 | 8 | 48 | 183.0 | 237.0 |
| Avg | | 149.4 | 207.7 | 30.2 | 8 | 50 | 178.5 | 271.0 |
| 400 | 0.5 | 149.0 | 192.5 | 24.3 | 8 | 46 | 160.5 | 301.0 |
| | | 155.0 | 192.5 | 28.6 | 8 | 46 | 160.0 | 209.0 |
| | | 155.0 | 192.5 | 27.4 | 8 | 46 | 160.0 | 209.0 |
| Avg | | 153.0 | 192.5 | 26.7 | 8 | 46 | 160.1 | 239.6 |
| 400 | 10 | 146.2 | 186.8 | 25.2 | 8 | 45 | 154.0 | 279.0 |
| | | 147.2 | 192.0 | 24.4 | 8 | 47 | 158.6 | 284.0 |
| | | 149.5 | 191.5 | 24.3 | 8 | 44 | 159.4 | 258.0 |
| Avg | | 147.6 | 190.1 | 24.6 | 8 | 45 | 157.3 | 273.6 |
| 400 | 100 | 144.0 | 189.5 | 25.4 | 8 | 46 | 156.0 | 271.8 |
| | | 144.5 | 192.5 | 23.4 | 8 | 47 | 158.5 | 264.5 |
| | | 141.2 | 194.5 | 24.8 | 8 | 45 | 161.0 | 270.5 |
| Avg | | 143.2 | 192.1 | 24.5 | 8 | 46 | 158.5 | 268.9 |
| 400 | 1000 | 143.5 | 189.5 | 25.7 | 7 | 46 | 155.0 | 273.0 |
| | | 148.5 | 191.0 | 25.5 | 8 | 44 | 160.2 | 267.0 |
| | | 147.5 | 190.0 | 26.2 | 8 | 46 | 157.5 | 267.0 |
| Avg | | 146.5 | 190.1 | 25.8 | 8 | 45 | 157.5 | 269.0 |

Table 22 (continued)

Tensile Properties of 0.062-In. Type 420 Stainless Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 600 | 0.5 | 171.0 | 191.5 | 27.0 | 6 | 47 | 170.0 | 257.0 |
| | | 153.0 | 189.0 | 30.4 | 6 | 49 | 176.0 | 328.0 |
| | | 159.9 | 192.0 | 25.6 | 7 | 50 | 178.5 | 265.0 |
| Avg | | 161.3 | 190.8 | 27.7 | 6 | 49 | 174.8 | 280.3 |
| 600 | 10 | 143.8 | 192.0 | 30.6 | 7 | 50 | 176.5 | 293.0 |
| | | 158.5 | 198.5 | 27.6 | 7 | 51 | 186.5 | 305.0 |
| | | 167.5 | 192.0 | 28.3 | 7 | 50 | 184.0 | 299.5 |
| Avg | | 156.6 | 194.2 | 28.8 | 7 | 50 | 182.3 | 299.2 |
| 600 | 100 | 147.2 | 190.8 | 28.1 | 6 | 50 | 181.5 | 317.5 |
| | | 142.5 | 193.2 | 27.8 | 7 | 48 | 180.2 | 263.5 |
| | | 142.1 | 188.5 | 27.8 | 6 | 49 | 178.5 | 265.0 |
| Avg | | 143.9 | 190.8 | 27.9 | 6 | 49 | 180.1 | 282.0 |
| 600 | 1000 | 138.4 | 185.0 | 30.2 | 6 | 48 | 174.0 | 312.0 |
| | | 156.8 | 190.5 | 29.5 | 6 | 50 | 166.8 | 286.0 |
| | | 143.8 | 190.2 | 27.4 | 7 | 50 | 176.8 | 332.0 |
| Avg | | 146.3 | 188.6 | 29.0 | 6 | 49 | 172.5 | 310.0 |
| 800 | 0.5 | 148.0 | 185.5 | 26.3 | 9.0 | 48 | 172.0 | 243.0 |
| | | 138.5 | 189.0 | 24.6 | 9.5 | 49 | 164.0 | 264.0 |
| | | 139.0 | 186.0 | 24.3 | 8.0 | 46 | 166.5 | 297.0 |
| Avg | | 141.8 | 186.8 | 25.1 | 9.0 | 48 | 167.5 | 268.0 |

Table 22 (continued)

Tensile Properties of 0.062-In. Type 420 Stainless Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 800 | 10 | 143.8 | 184.5 | 26.7 | 8.0 | 47 | 158.2 | 289.0 |
| | | 130.6 | 180.5 | 25.1 | 8.5 | 46 | 154.0 | 282.0 |
| | | 133.5 | 185.0 | 23.9 | 8.0 | 48 | 162.6 | 271.0 |
| Avg | | 136.0 | 183.3 | 25.2 | 8.0 | 47 | 158.3 | 280.7 |
| 800 | 100 | 136.8 | 181.0 | 22.8 | 8.5 | 47 | 150.5 | 228.5 |
| | | 137.5 | 185.8 | 24.1 | 8.0 | 47 | 166.2 | 264.0 |
| | | 134.5 | 180.6 | 24.3 | 8.0 | 45 | 159.2 | 251.0 |
| Avg | | 136.3 | 182.5 | 23.7 | 8.0 | 46 | 158.6 | 247.8 |
| 800 | 1000 | 133.5 | 176.5 | 25.7 | 6.0 | 47 | 151.6 | 240.0 |
| | | 132.3 | 174.0 | 27.3 | 6.0 | 48 | 147.8 | 233.0 |
| | | 141.0 | 180.2 | 28.7 | 6.0 | 46 | 160.9 | 239.5 |
| Avg | | 135.6 | 176.9 | 27.2 | 6.0 | 47 | 153.4 | 237.5 |
| 1000 | 0.5 | 85.0 | 88.2 | 25.0 | 13 | 47 | 65.0 | 138.C |
| | | 60.4 | 83.4 | 25.8 | 14 | 47 | 57.0 | 139.0 |
| | | 76.8 | 88.2 | 26.7 | 16 | 47 | 46.0 | 117.0 |
| Avg | | 74.1 | 86.6 | 25.8 | 14 | 47 | 56.0 | 131.3 |
| 1000 | 10 | 77.2 | 80.8 | 21.6 | 19 | 33 | 39.5 | 119.5 |
| | | 73.8 | 80.9 | 21.5 | 20 | 31 | 39.2 | 136.2 |
| | | 77.4 | 85.5 | 19.0 | 20 | 33 | 45.6 | 136.0 |
| Avg | | 76.1 | 82.4 | 20.7 | 20 | 32 | 41.4 | 130.6 |

Table 22 (continued)

Tensile Properties of 0.062-In. Type 420 Stainless Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 1000 | 100 | 62.9 | 70.0 | 17.8 | 17 | 32 | 34.6 | 114.2 |
| | | 62.0 | 69.0 | 22.5 | 17 | 37 | 34.5 | 93.6 |
| | | 62.5 | 69.0 | 26.5 | 18 | 35 | 34.5 | 116.0 |
| Avg | | 62.5 | 69.3 | 22.3 | 17 | 35 | 34.5 | 107.9 |
| 1000 | 1000 | 61.0 | 65.7 | 20.6 | 22 | 33 | 6.4 | 17.6 |
| | | 61.0 | 65.7 | 20.9 | 22 | 35 | 22.4 | 62.5 |
| | | 59.3 | 65.7 | 23.1 | 13 | 33 | 22.4 | 66.5 |
| Avg | | 60.4 | 65.7 | 21.5 | 19 | 34 | 17.1 | 48.9 |

1. Hardness determinations at room temperature after tests.
2. Rupture strength based on original cross section.
3. Rupture strength based on final cross section.
4. Heat treatment — 1800° F 15 min argon atmosphere, O. Q., 900° F 3 hr, A. C.

Table 23

Tensile Strength of 3/16-In. Type 420 Stainless Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC |
| RT | | | | | | | 228.0 | 45 |
| | | | | | | | 224.0 | 45 |
| | | | | | | | 228.6 | 45 |
| Avg | | | | | | | 226.8 | 45 |
| 400 | 213.0 | 47 | 208.0 | 47 | 207.0 | 46 | 215.0 | 47 |
| | 216.0 | 48 | 212.0 | 47 | 207.0 | 46 | 206.0 | 47 |
| | 212.0 | 47 | 210.0 | 47 | 209.0 | 45 | 207.0 | 46 |
| Avg | 213.7 | 47 | 210.0 | 47 | 207.7 | 46 | 209.3 | 47 |
| 600 | 207.0 | 46 | 208.0 | 47 | 205.5 | 46 | 201.0 | 46 |
| | 203.0 | 46 | 207.0 | 47 | 205.0 | 45 | 209.2 | 48 |
| | 207.0 | 46 | 201.0 | 47 | 205.2 | 45 | 201.0 | 48 |
| Avg | 205.7 | 46 | 205.3 | 47 | 205.2 | 45 | 203.7 | 47 |
| 800 | 195.5 | 49 | 195.0 | 47 | 195.0 | 45 | 185.0 | 46 |
| | 197.5 | 46 | 203.0 | 48 | 187.0 | 46 | 183.5 | 47 |
| | 203.0 | 48 | 193.5 | 47 | 193.0 | 45 | 186.0 | 46 |
| Avg | 198.7 | 48 | 197.2 | 47 | 191.7 | 45 | 184.8 | 46 |

Table 23 (continued)

Tensile Strength of 3/16-In. Type 420 Stainless Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC |
| 1000 | 118.5 | 44 | 84.5 | 35 | 76.2 | 29 | 64.6 | 29 |
| | 122.0 | 42 | 86.3 | 34 | 72.0 | 30 | 63.6 | 27 |
| | 120.0 | 44 | 87.5 | 34 | 73.0 | 30 | 63.0 | – |
| Avg | 120.2 | 43 | 86.1 | 34 | 73.7 | 30 | 63.7 | 28 |

1. Ultimate tensile strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment — 1800° F 15 min argon atmosphere, O. Q., 900° F 3 hr, A. C.

Table 24

Compressive Properties of 0.062-In. Type 420 Stainless Steel[3] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | CYS[1] 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| RT | | | | | | | | | | 184.0 | 29.3 | 48 |
| | | | | | | | | | | 176.0 | 28.7 | 48 |
| | | | | | | | | | | 179.0 | 28.6 | 46 |
| Avg | | | | | | | | | | 179.6 | 28.9 | 47 |
| 400 | 178.0 | 27.7 | 48 | 174.0 | 25.3 | 47 | 172.1 | 25.9 | 47 | 166.5 | 29.3 | 47 |
| | 171.5 | 27.4 | 48 | 166.0 | 28.6 | 45 | 172.5 | 26.3 | 48 | 170.5 | 27.3 | 47 |
| | 160.5 | 29.6 | 49 | 165.5 | 25.8 | 45 | 169.0 | 26.3 | 47 | 164.0 | 26.5 | 44 |
| Avg | 170.0 | 28.2 | 48 | 168.5 | 26.6 | 46 | 171.2 | 26.2 | 47 | 167.0 | 27.7 | 46 |
| 600 | 166.0 | 25.8 | 47 | 159.5 | 24.0 | 45 | 157.0 | 29.4 | 48 | 159.0 | 28.8 | 47 |
| | 167.5 | 26.6 | 50 | 163.8 | 26.4 | 45 | 154.0 | 29.4 | 48 | 163.0 | 27.1 | 47 |
| | 161.5 | 29.0 | 48 | 156.5 | 27.3 | 46 | 155.0 | 27.5 | 48 | 163.0 | 27.3 | 49 |
| Avg | 165.0 | 27.1 | 48 | 159.9 | 25.9 | 45 | 155.3 | 28.8 | 48 | 161.7 | 27.7 | 48 |
| 800 | 172.5 | 27.0 | 47 | 163.0 | 25.0 | 50 | 152.0 | 21.0 | 50 | 148.8 | 22.8 | 47 |
| | 148.0 | 25.4 | 47 | 154.8 | 24.2 | 50 | 149.5 | 26.7 | 47 | 153.0 | 21.1 | 46 |
| | 152.0 | 25.7 | 48 | 156.7 | 28.8 | 49 | 161.0 | 24.9 | 51 | 154.0 | 23.9 | 46 |
| Avg | 157.5 | 26.0 | 47 | 158.2 | 26.0 | 50 | 154.2 | 24.2 | 49 | 151.9 | 22.6 | 46 |

Ta 24 (continued)

Compressive Properties of 0.062-In. Type 420 Stainless Steel[3] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | CYS[1] 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| 1000 | 88.3 | 25.0 | 39 | 88.0 | 21.7 | 38 | 76.7 | 24.1 | 35 | 62.0 | 23.2 | 24 |
| | 89.0 | 24.3 | 34 | 84.0 | 17.4 | 38 | 68.3 | 22.1 | 32 | 63.7 | 23.4 | 26 |
| | 101.0 | 20.3 | 40 | 85.8 | 20.4 | 38 | 68.0 | 18.3 | 32 | 61.7 | 21.2 | 26 |
| Avg | 92.8 | 23.2 | 38 | 85.9 | 19.8 | 38 | 71.0 | 21.5 | 33 | 62.7 | 22.6 | 25 |

1. Compressive yield strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment — 1800° F 15 min argon atmosphere, O.Q., 900° F 3 hr, A. C.

Table 25

Shear Strength of 3/16-In. Type 420 Stainless Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | USS[1] 1000 psi | Hard[2] RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC |
| RT | | | | | | | 144.0 | 37 |
| | | | | | | | 143.0 | 35 |
| | | | | | | | 133.8 | 35 |
| Avg | | | | | | | 140.3 | 36 |
| 400 | 125.0 | 42 | 131.2 | 47 | 126.5 | 46 | 126.5 | 46 |
| | 128.2 | 43 | 129.2 | 46 | 125.2 | 47 | 128.2 | 45 |
| | 128.2 | 42 | 128.2 | 47 | 128.5 | 46 | 121.0 | 46 |
| Avg | 127.1 | 42 | 129.5 | 47 | 126.7 | 46 | 125.2 | 46 |
| 600 | 128.5 | 47 | 120.0 | 47 | 128.2 | 23 | 118.8 | 33 |
| | 126.5 | 43 | 123.0 | 45 | 125.0 | 24 | 124.0 | 24 |
| | 125.5 | 44 | 122.0 | 42 | 126.5 | 24 | 124.0 | 23 |
| Avg | 126.8 | 45 | 121.7 | 45 | 126.6 | 24 | 122.3 | 27 |
| 800 | 131.8 | 43 | 126.2 | 41 | 128.0 | 42 | 122.0 | 40 |
| | 132.0 | 42 | 126.0 | 43 | 127.0 | 42 | 124.0 | 42 |
| | 123.0 | 41 | 129.4 | 41 | 127.0 | 41 | 134.0 | 42 |
| Avg | 128.9 | 42 | 127.2 | 42 | 127.3 | 42 | 126.7 | 41 |

Table 25 (continued)

Shear Strength of 3/16-In. Type 420 Stainless Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | USS[1] 1000 psi | Hard[2] RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC |
| 1000 | 86.3 | 39 | 68.8 | 38 | 66.2 | 30 | 50.0 | 22 |
| | 86.1 | 44 | 78.5 | 31 | 54.2 | 28 | 45.8 | 25 |
| | 86.6 | 38 | 72.2 | 38 | 54.2 | 29 | 47.2 | – |
| Avg | 86.3 | 40 | 73.2 | 36 | 58.2 | 29 | 47.7 | 24 |

1. Ultimate shear strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment — 1800° F 15 min argon atmosphere, O.Q., 900° F 3 hr, A. C.

## Table 26

Bearing Properties[4] of 0.062-In. Type 420 Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] | UBS[2] | Hard[3] | BYS | UBS | Hard | BYS | UBS | Hard | BYS | UBS | Hard |
| | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N |
| RT | | | | | | | | | | 267.0 | 324.0 | 47 |
| | | | | | | | | | | 255.0 | 328.0 | 47 |
| | | | | | | | | | | 258.0 | 324.0 | 47 |
| Avg | | | | | | | | | | 260.0 | 325.3 | 47 |
| 400 | 243.0 | 304.0 | 47 | 203.0 | 305.0 | 47 | 261.0 | 317.0 | 47 | 262.0 | 292.0 | 47 |
| | 272.5 | 304.0 | 48 | – | 299.0 | 46 | 269.5 | 315.0 | 48 | 261.0 | 296.0 | 47 |
| | 243.0 | 304.0 | 48 | 195.5 | 294.0 | 47 | 250.0 | 303.0 | 47 | 272.0 | 305.0 | 47 |
| Avg | 252.8 | 304.0 | 48 | 199.2 | 299.3 | 47 | 260.2 | 311.7 | 47 | 265.0 | 297.7 | 47 |
| 600 | 248.5 | 297.0 | 49 | 251.0 | 314.0 | 48 | 262.0 | 313.0 | 45 | 250.0 | 301.5 | 47 |
| | 240.0 | 299.0 | 48 | 252.0 | 311.0 | 48 | 235.5 | 296.0 | 48 | 260.0 | 304.0 | 47 |
| | 241.0 | 299.5 | 48 | 249.6 | 305.0 | 44 | 252.0 | 295.0 | 43 | 234.5 | 307.0 | 48 |
| Avg | 243.2 | 298.5 | 48 | 250.9 | 310.0 | 47 | 249.8 | 301.3 | 47 | 248.2 | 304.2 | 47 |
| 800 | 242.5 | 291.0 | 45 | 248.0 | 302.0 | 47 | 246.0 | 296.0 | 47 | 244.0 | 289.0 | 48 |
| | 222.0 | 297.0 | 46 | 245.0 | 286.0 | 46 | 248.0 | 302.0 | 48 | 243.0 | 290.5 | 47 |
| | 261.0 | 291.0 | 46 | 256.0 | 307.0 | 47 | 251.0 | 304.0 | 48 | 244.0 | 285.5 | 49 |
| Avg | 241.8 | 293.0 | 46 | 249.7 | 298.3 | 47 | 248.3 | 300.7 | 48 | 243.7 | 288.3 | 48 |

Table 26 (continued)

Bearing Properties[4] of 0.062-In. Type 420 Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp ° F | BYS[1] 1000 psi | UBS[2] 1000 psi | Hard[3] R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N |
| 1000 | 159.0 | 175.0 | 40 | 116.5 | 135.8 | 38 | 101.5 | 112.2 | 35 | 82.8 | 103.0 | 29 |
| | 143.0 | 169.2 | 38 | 123.0 | 132.2 | 38 | 100.0 | 111.0 | 36 | 88.0 | 101.5 | 27 |
| | 144.0 | 171.5 | 40 | 119.9 | 134.0 | 39 | 101.5 | 111.2 | 35 | 89.5 | 106.5 | 29 |
| Avg | 148.7 | 171.9 | 39 | 119.8 | 133.7 | 38 | 101.0 | 111.5 | 35 | 86.8 | 103.7 | 28 |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge-distance to hole-diameter ratio 1.5.
5. Heat treatment — 1800° F 15 min argon atmosphere, O.Q., 900° F 3 hr, A. C.

Table 27

Bearing Properties[4] of 0.062-In. Type 420 Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr / Temp °F | 1/2 BYS[1] (1000 psi) | 1/2 UBS[2] (1000 psi) | 1/2 Hard[3] R45N | 10 BYS (1000 psi) | 10 UBS (1000 psi) | 10 Hard R45N | 100 BYS (1000 psi) | 100 UBS (1000 psi) | 100 Hard R45N | 1000 BYS (1000 psi) | 1000 UBS (1000 psi) | 1000 Hard R45N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RT | | | | | | | | | | 334.0 | 435.0 | 49 |
| | | | | | | | | | | 325.0 | 428.0 | 49 |
| | | | | | | | | | | 303.0 | 431.0 | 49 |
| Avg | | | | | | | | | | 320.7 | 431.3 | 49 |
| 400 | 303.0 | 408.0 | 48 | 289.0 | 400.0 | 47 | – | 405.0 | 49 | 315.0 | 400.0 | 45 |
| | 288.0 | 394.0 | 47 | 317.0 | 404.0 | 48 | 305.0 | 404.0 | 50 | 325.0 | 407.0 | 45 |
| | 300.0 | 406.0 | 48 | 297.0 | 410.0 | 48 | 308.0 | 406.0 | 49 | 315.0 | 406.0 | 45 |
| Avg | 297.0 | 402.7 | 48 | 301.0 | 404.7 | 48 | 306.5 | 405.0 | 49 | 318.0 | 404.3 | 45 |
| 600 | 293.0 | 401.0 | 50 | 329.5 | 386.0 | 49 | 283.0 | 383.0 | 49 | 273.0 | 388.0 | 47 |
| | 309.0 | 401.0 | 49 | 273.0 | 400.0 | 49 | 290.0 | 383.5 | 49 | 295.0 | 386.5 | 47 |
| | 309.0 | 401.0 | 50 | 295.0 | 395.5 | 49 | 285.0 | 378.5 | 47 | 294.0 | 392.0 | 47 |
| Avg | 303.7 | 401.0 | 50 | 299.2 | 393.8 | 49 | 286.0 | 381.7 | 48 | 387.3 | 388.8 | 47 |
| 800 | 305.0 | 400.0 | 44 | 289.0 | 374.0 | 47 | 293.5 | 392.0 | 48 | 285.0 | 369.0 | 47 |
| | 309.0 | 394.0 | 45 | 275.0 | 390.0 | 49 | 294.0 | 392.0 | 48 | 284.0 | 369.0 | 47 |
| | 242.5 | 364.0 | 49 | 277.0 | 379.0 | 48 | 271.0 | 392.0 | 47 | 274.0 | 367.0 | 48 |
| Avg | 285.5 | 386.0 | 46 | 281.3 | 381.0 | 48 | 286.0 | 392.0 | 48 | 281.0 | 368.3 | 47 |

Table 27 (continued)

Bearing Properties[4] of 0.062-In. Type 420 Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp ° F | BYS[1] 1000 psi | UBS[2] 1000 psi | Hard[3] R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N |
| 1000 | 160.0 | 193.5 | 37 | 147.8 | 166.0 | 38 | 113.7 | 145.7 | 32 | 109.0 | 138.0 | 28 |
| | 166.5 | 196.2 | 36 | 137.5 | 163.0 | 39 | 105.7 | 146.0 | 32 | 109.0 | 131.5 | 28 |
| | 189.0 | 206.0 | 41 | 147.8 | 169.0 | 38 | 117.0 | 144.5 | 32 | 107.0 | 135.8 | 28 |
| Avg | 171.8 | 198.6 | 38 | 144.4 | 166.0 | 38 | 112.1 | 145.4 | 32 | 108.1 | 135.1 | 28 |

1. Bearing yield strength
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge-distance to hole-diameter ratio 2.0
5. Heat treatment — 1800° F 15 min argon atmosphere, O.Q., 900° F 3 hr, A.C.

## 10.5 Type 422 Stainless Steel Sheet, Quenched and Tempered

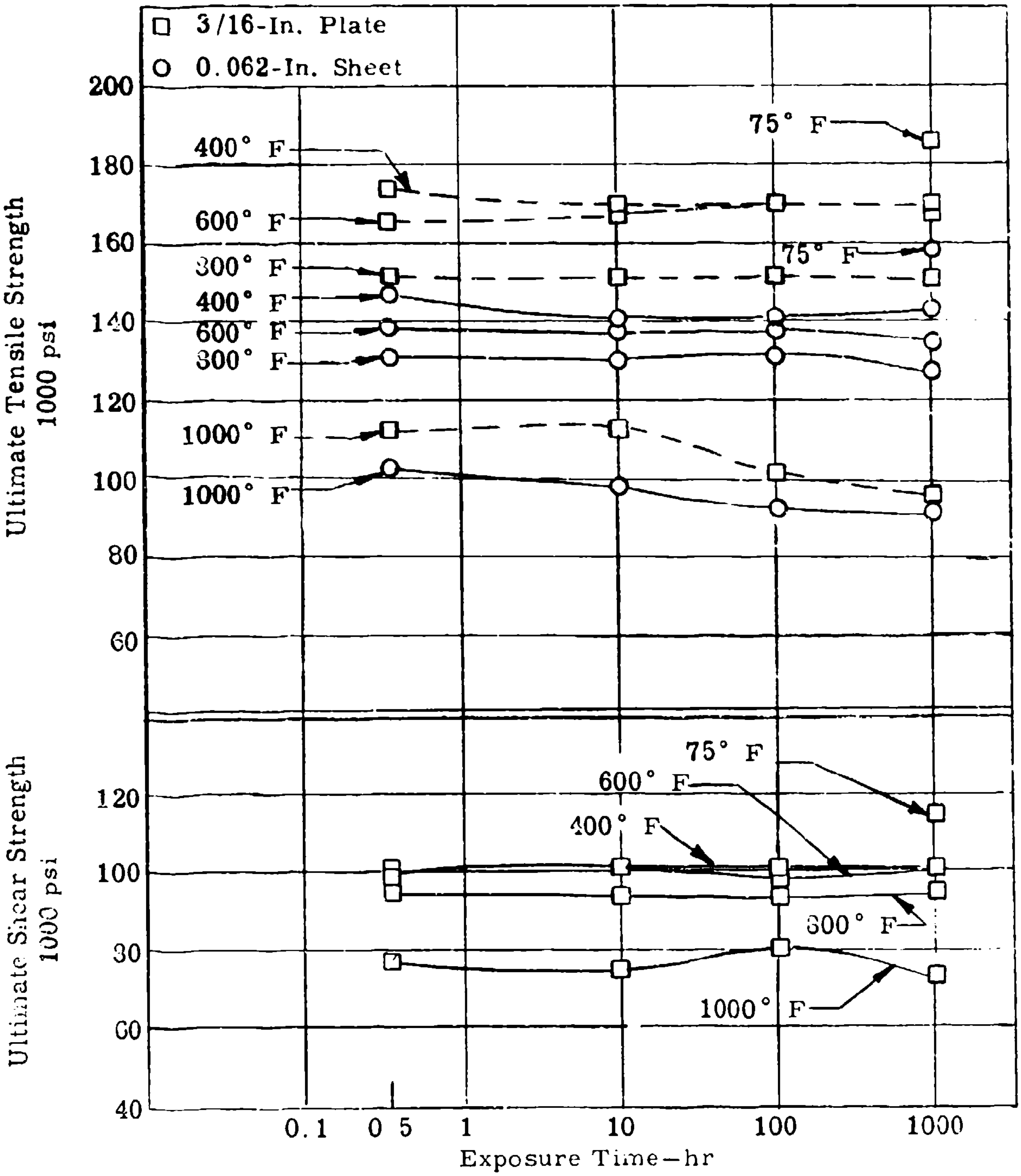


Fig. 99. Effect of exposure time on the ultimate tensile strength and ultimate shear strength of quenched and tempered Type 422 stainless steel at different temperatures.

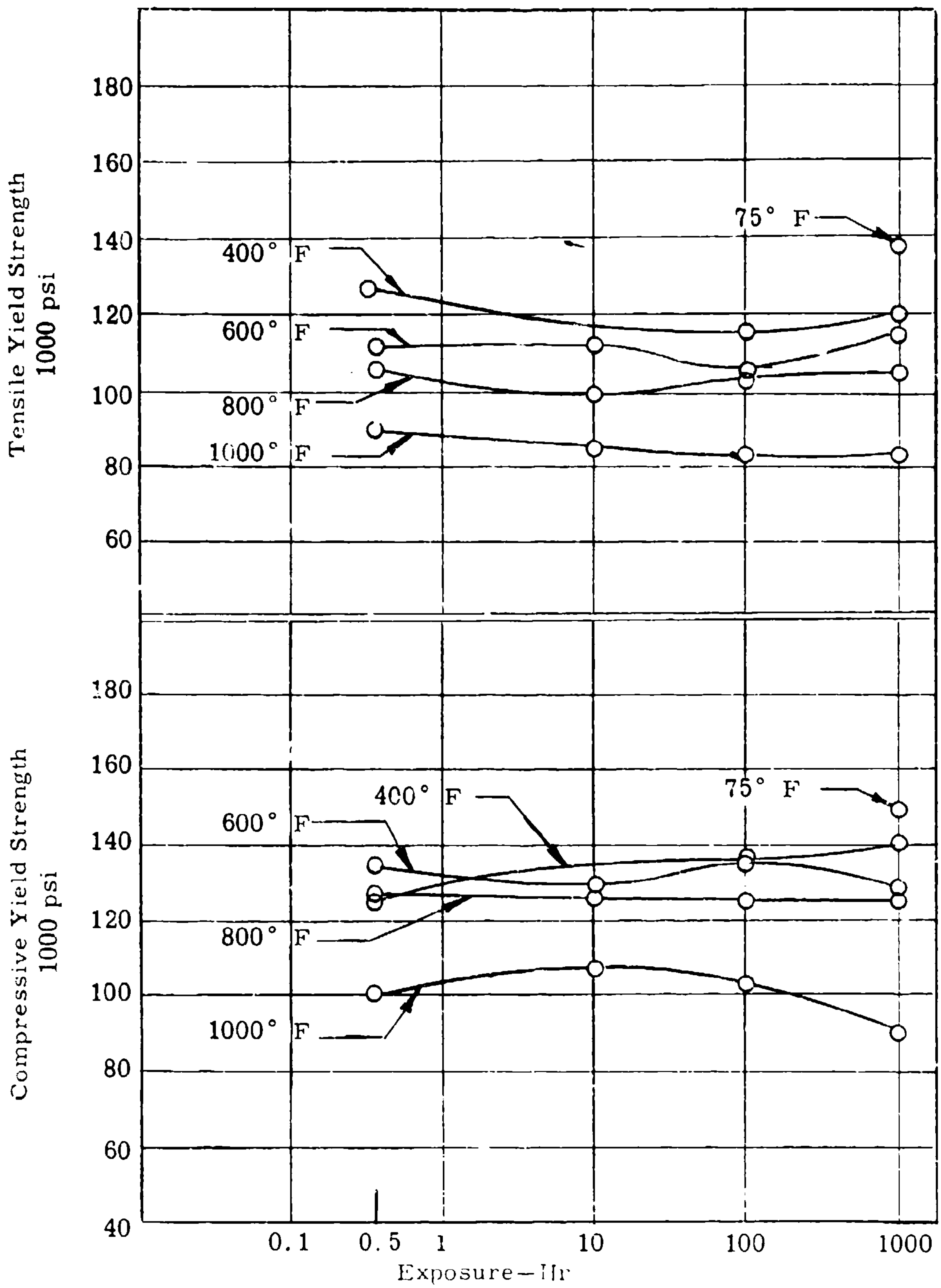


Fig. 100 Effect of exposure time on the tensile and compressive yield strength of quenched and tempered Type 422 stainless steel sheet at different temperatures.

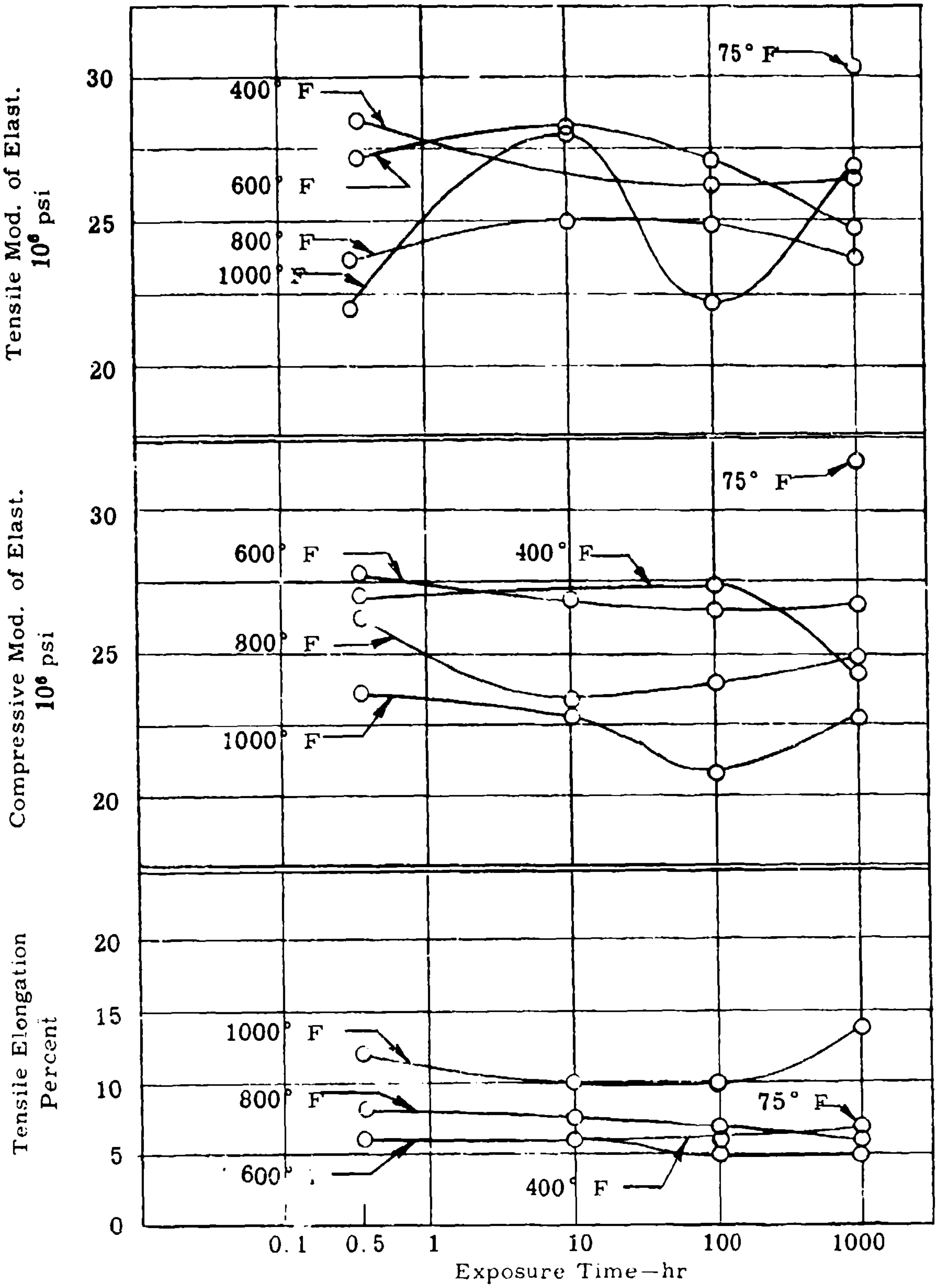


Fig. 101. Effect of exposure time on the tensile and compressive moduli of elasticity and percent elongation of quenched and tempered Type 422 stainless steel sheet at different temperatures.

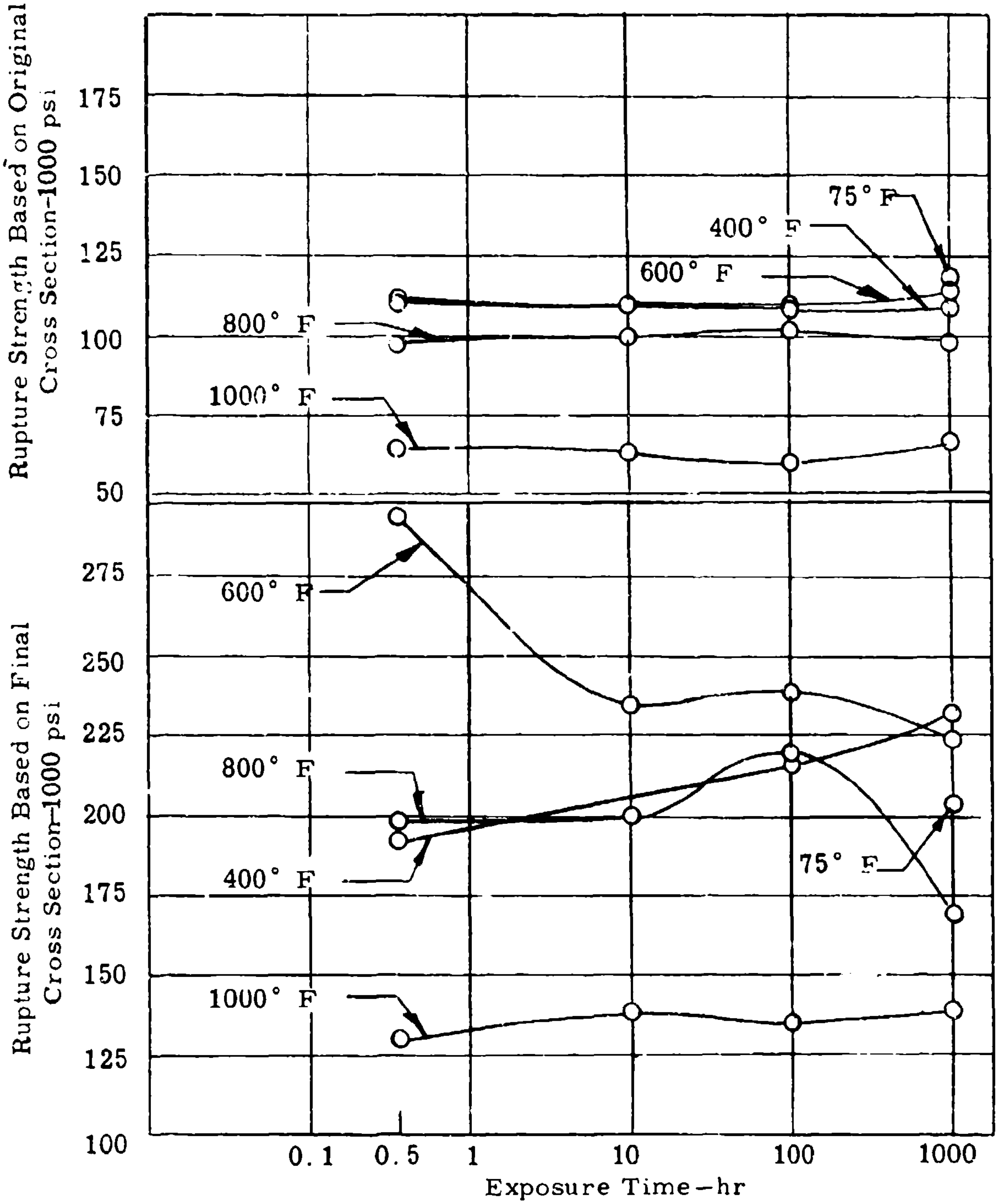


Fig. 102. Effect of exposure time on the tensile rupture strength of quenched and tempered Type 422 stainless steel sheet at different temperatures.

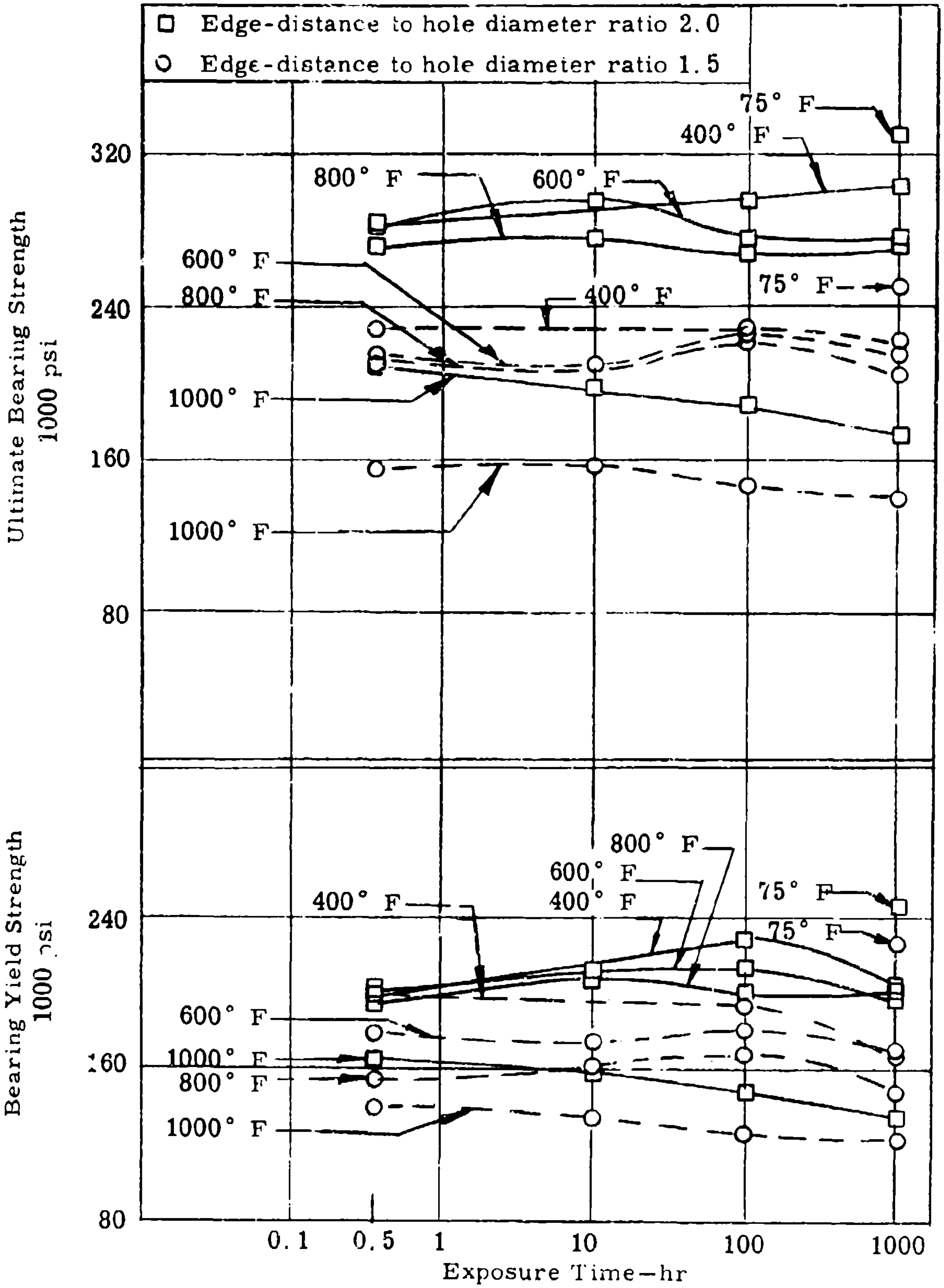


Fig. 103. Effect of exposure time on the bearing ultimate and yield strengths of quenched and tempered Type 422 stainless steel sheet at different temperatures.

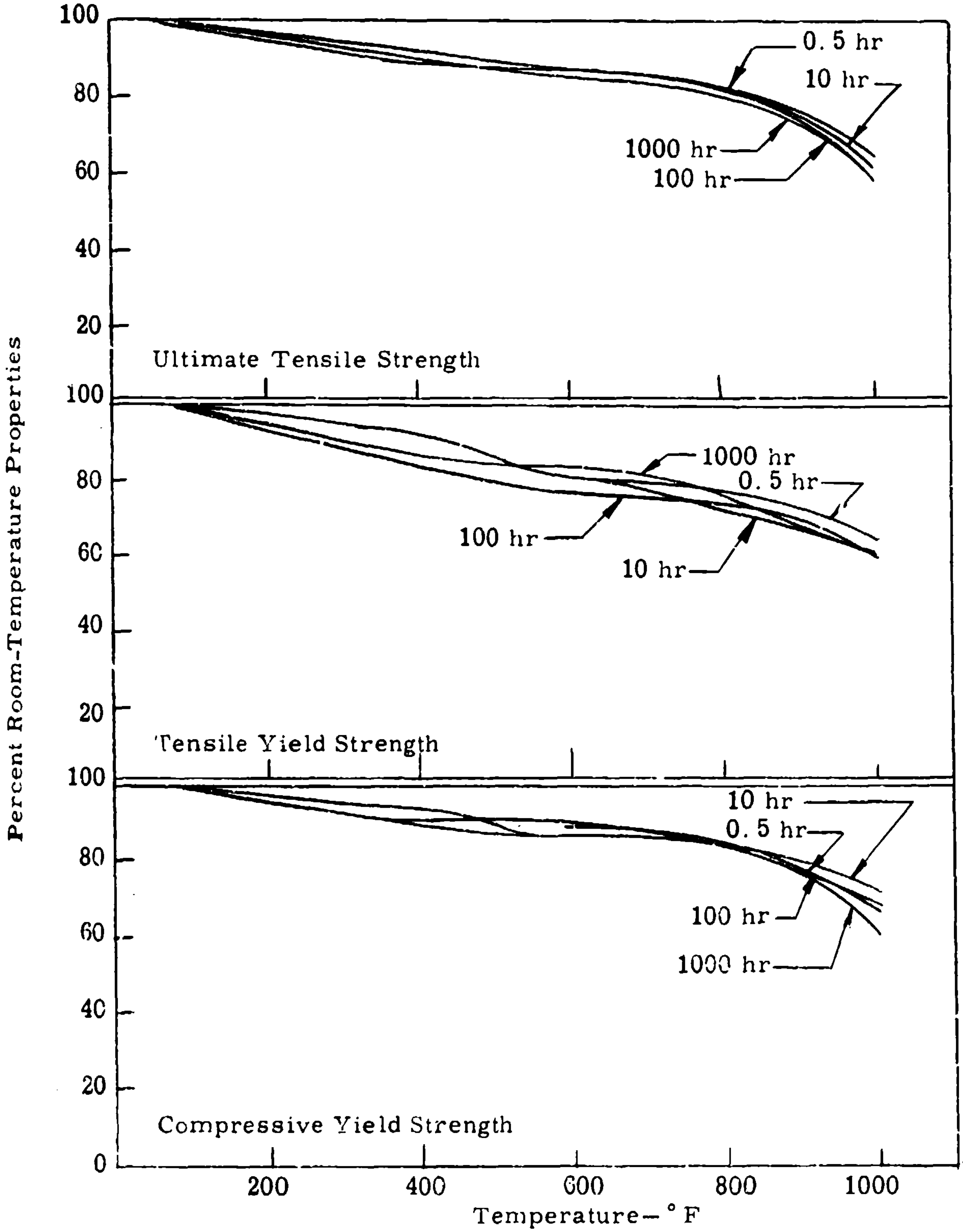


Fig. 104. Elevated-temperature strength properties as percent of room-temperature properties for quenched and tempered Type 422 stainless steel sheet at different exposure times.

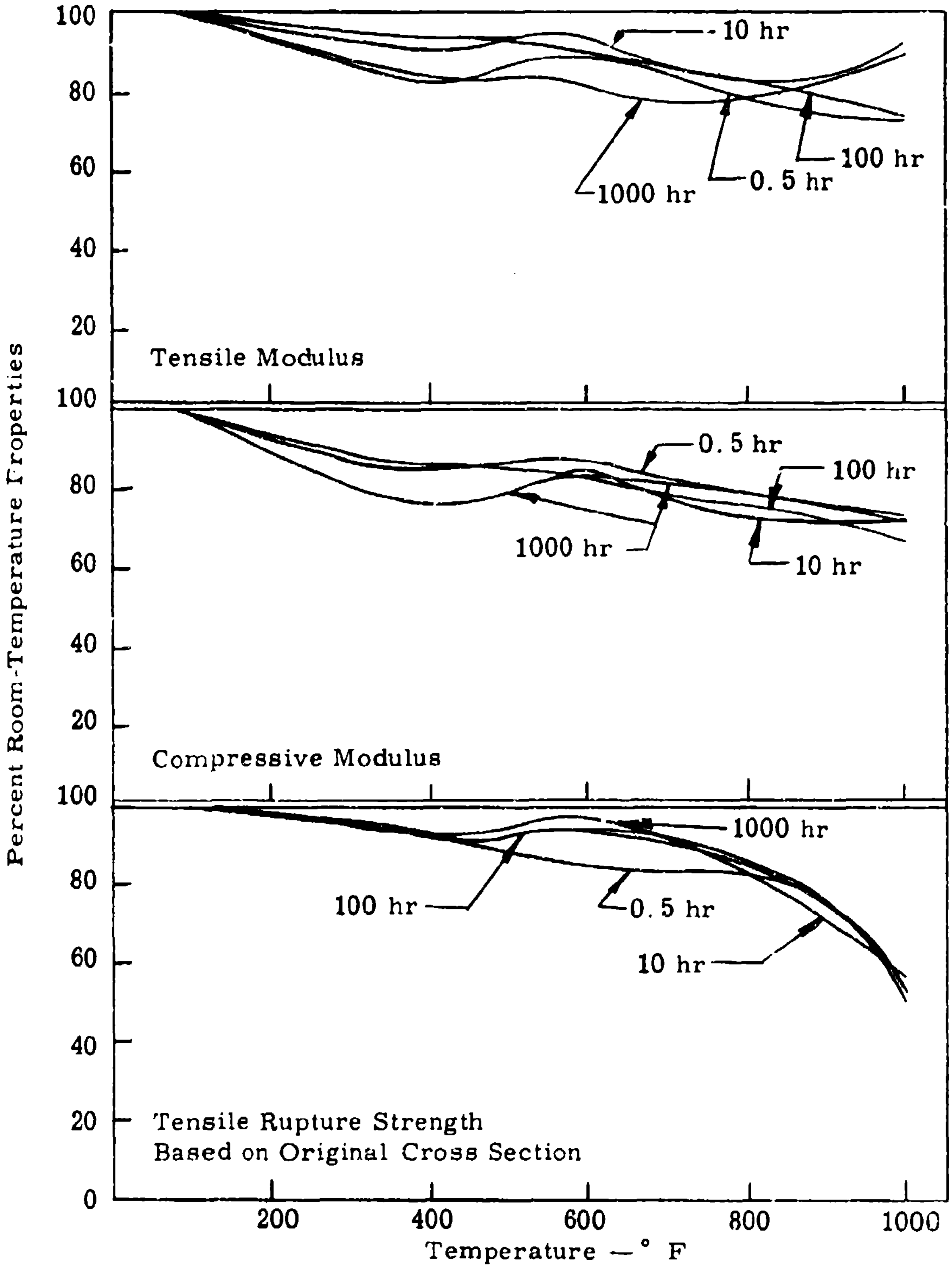


Fig. 105. Elevated-temperature properties as percent of room-temperature properties for quenched and tempered Type 422 stainless steel sheet at different exposure times.

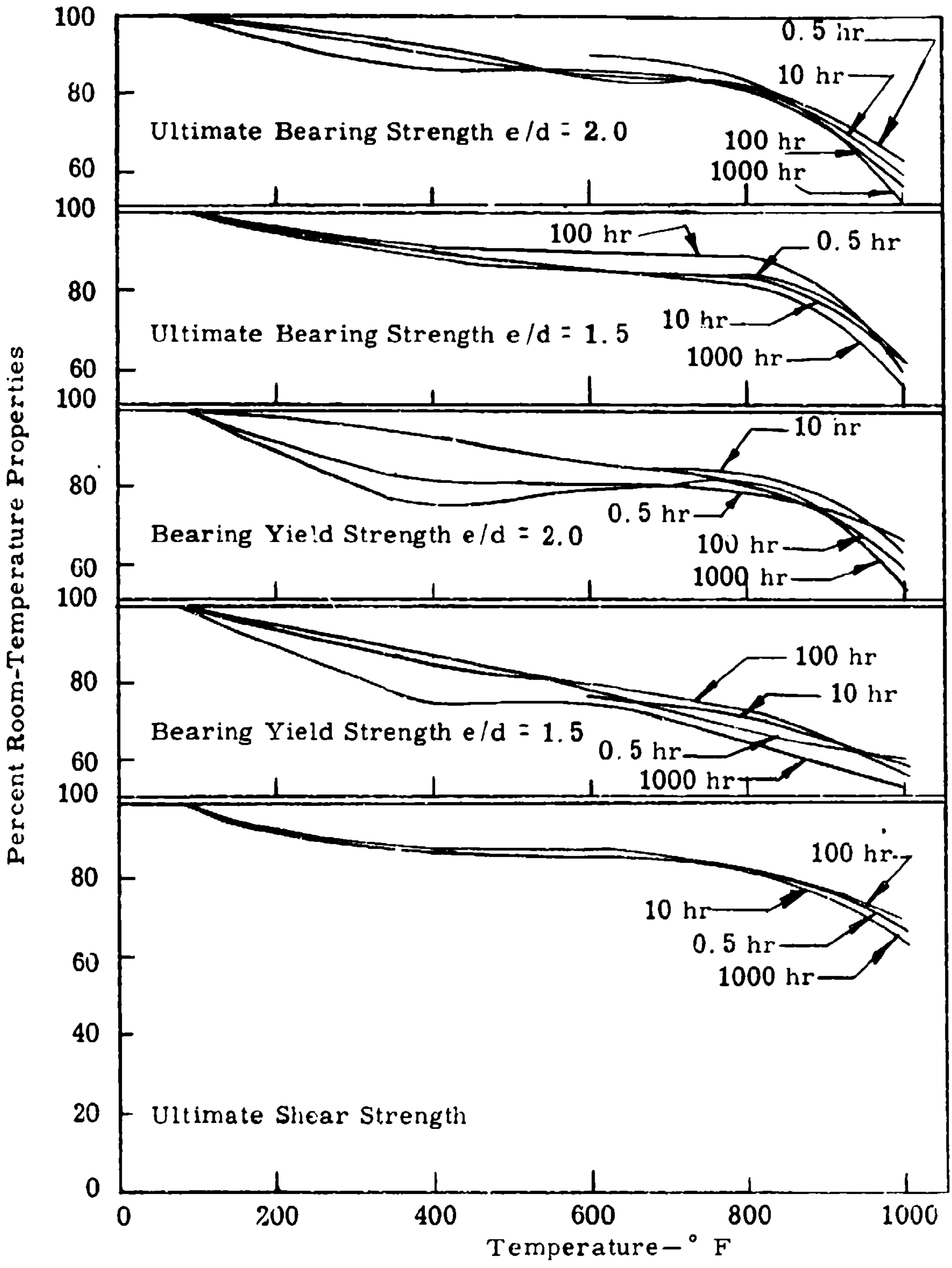


Fig. 106. Elevated-temperature strength properties as percent of room-temperature properties for quenched and tempered Type 422 stainless steel sheet at different exposure times.

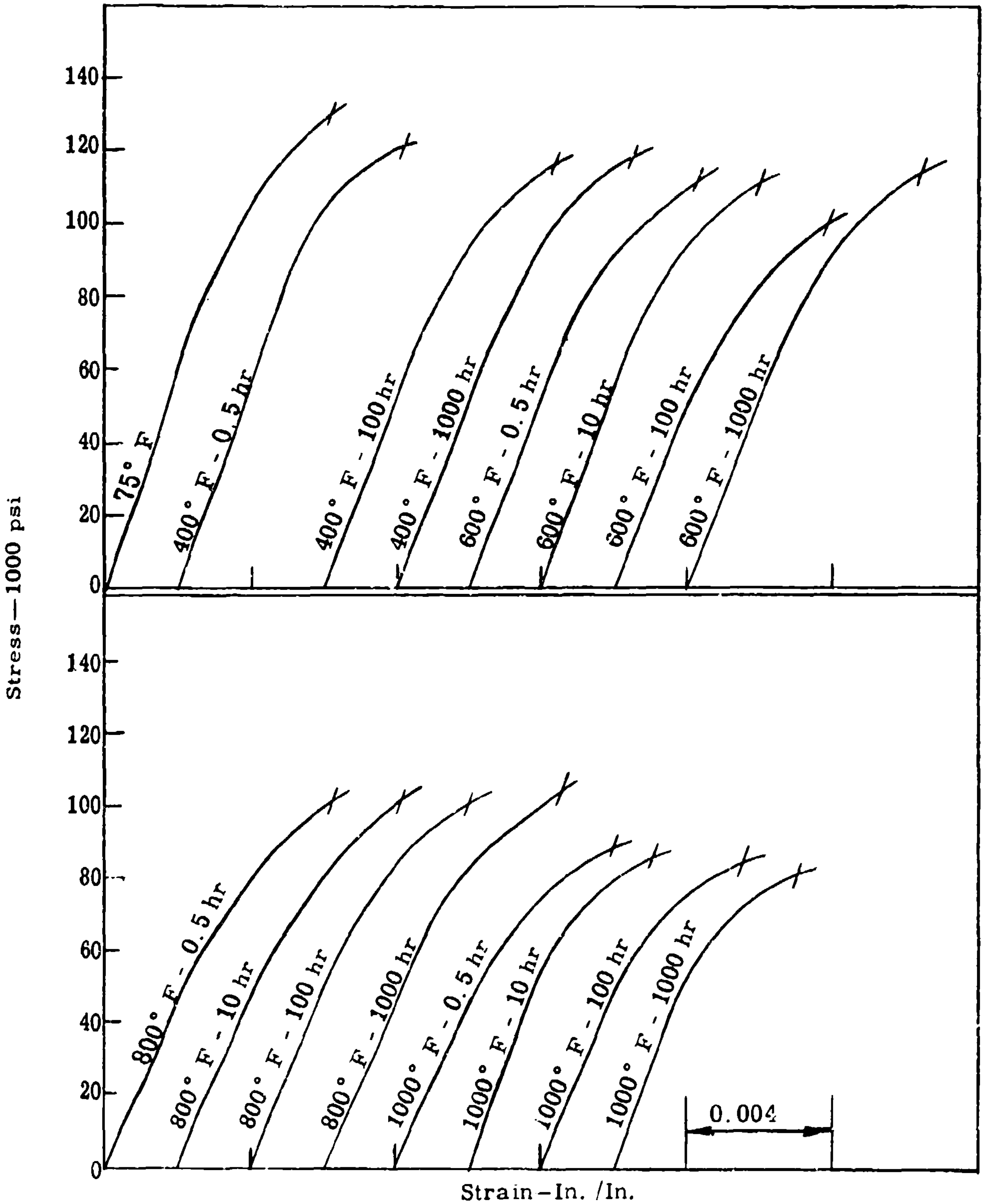


Fig. 107. Tensile stress-strain curves for quenched and tempered Type 422 stainless steel sheet at various temperatures and exposure times

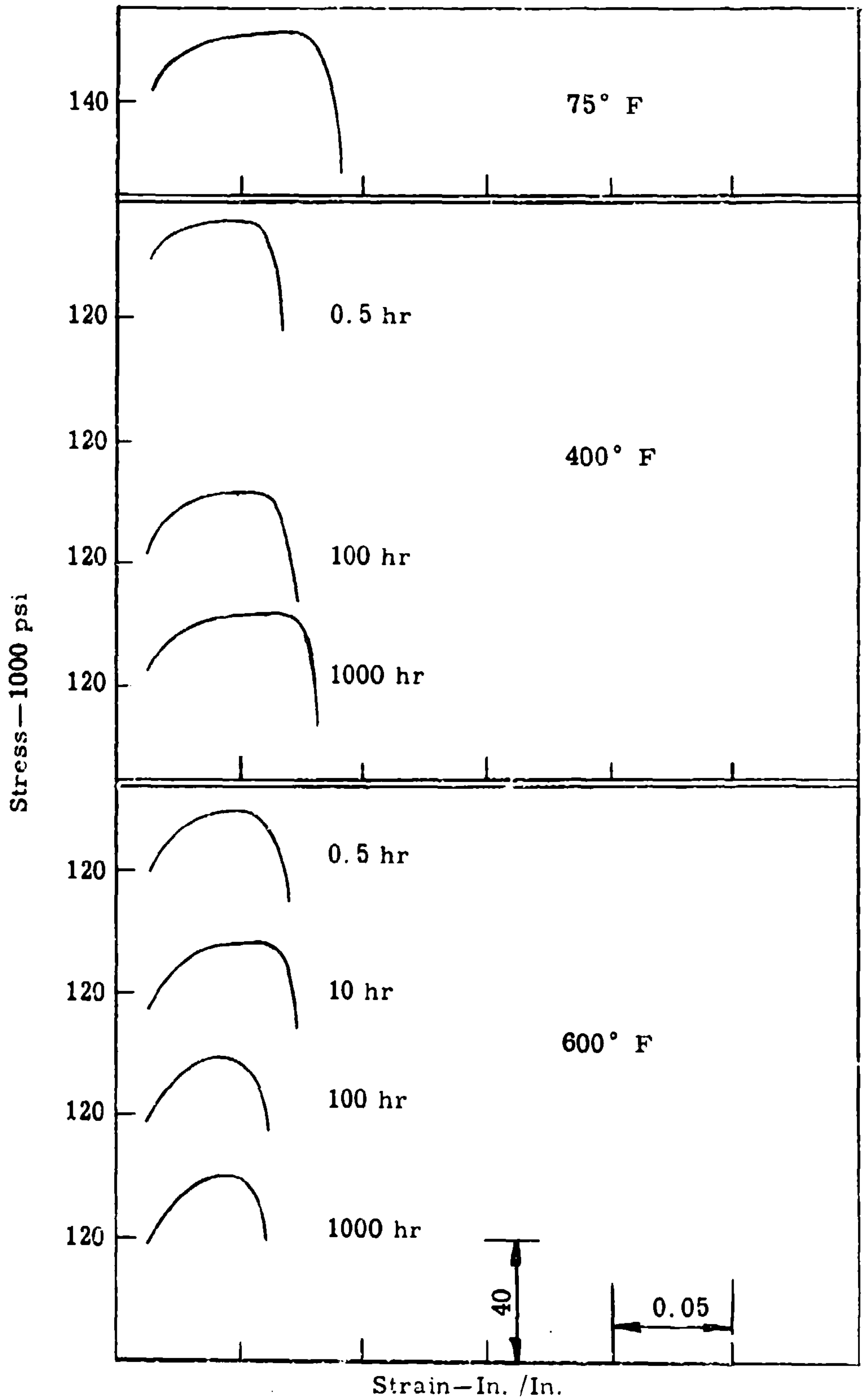


Fig. 108. **Tensil Postyield stress-strain curves for quenched and tempered Type 422 stainless steel sheet at various temperatures and exposure times**

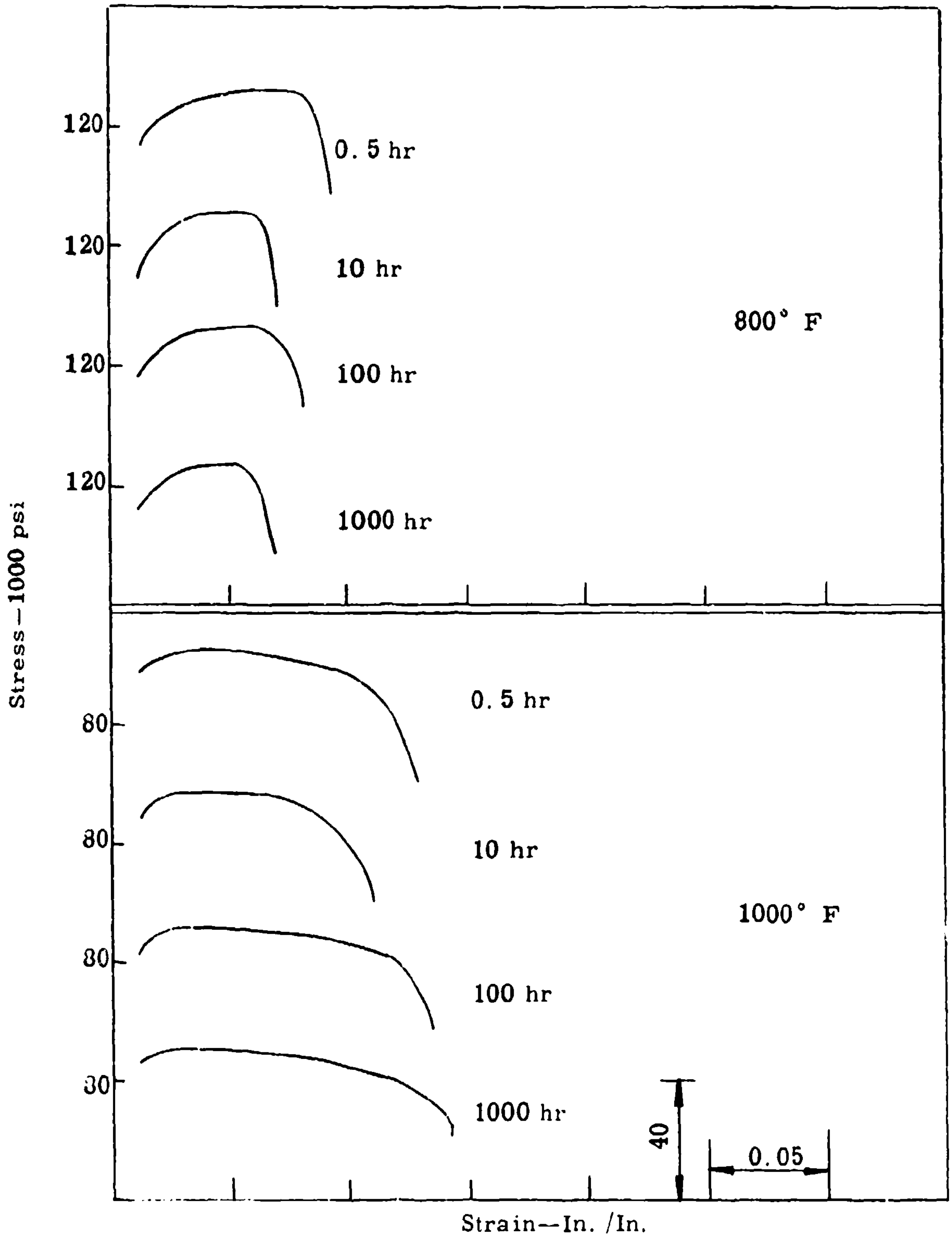


Fig. 109 Tensile postyield stress-strain curves for quenched and tempered Type 422 stainless steel sheet at various temperatures and exposure times.

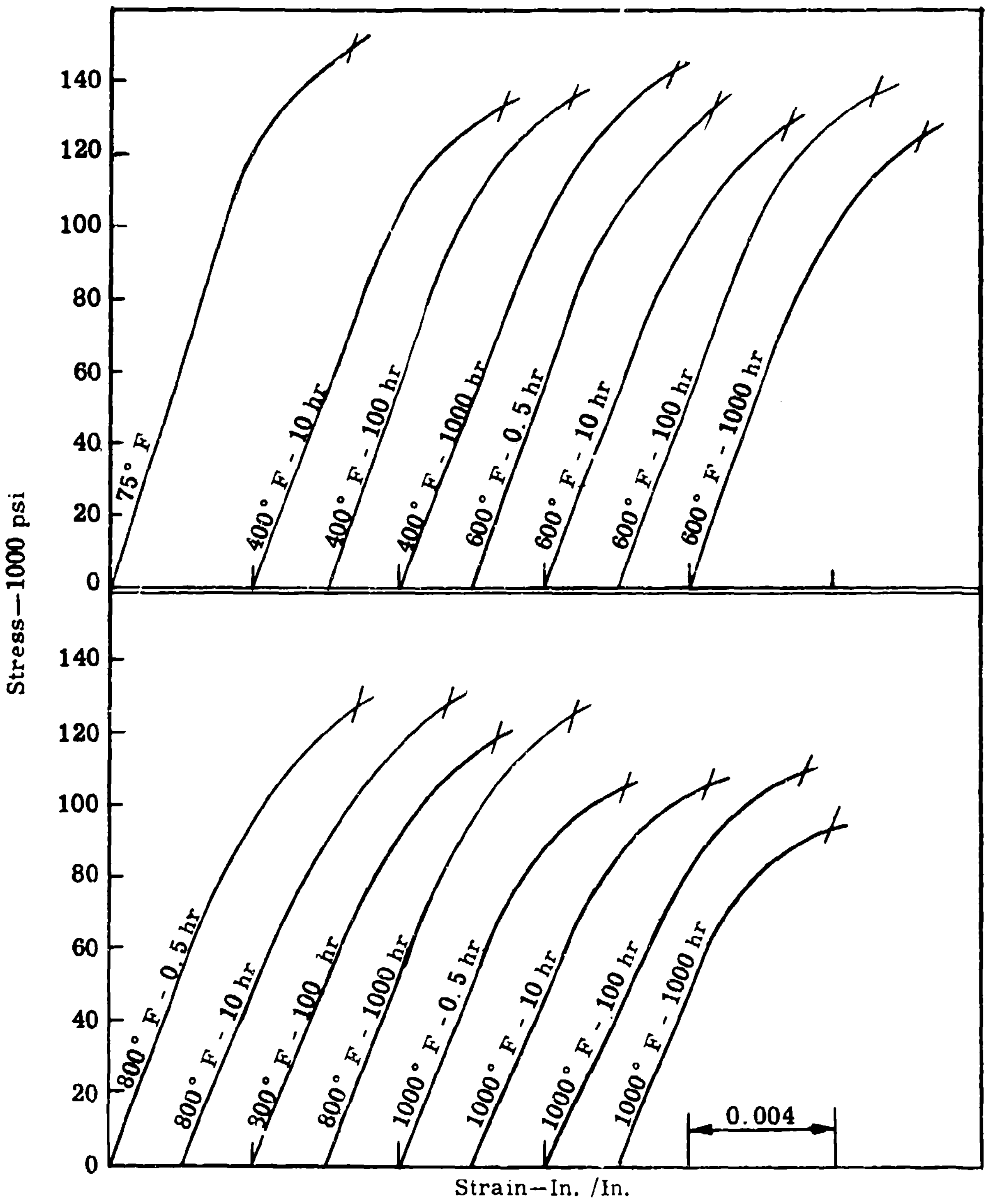


Fig. 110. Compressive-stress-strain curves for quenched and tempered Type 422 stainless steel sheet at various temperatures and exposure times.

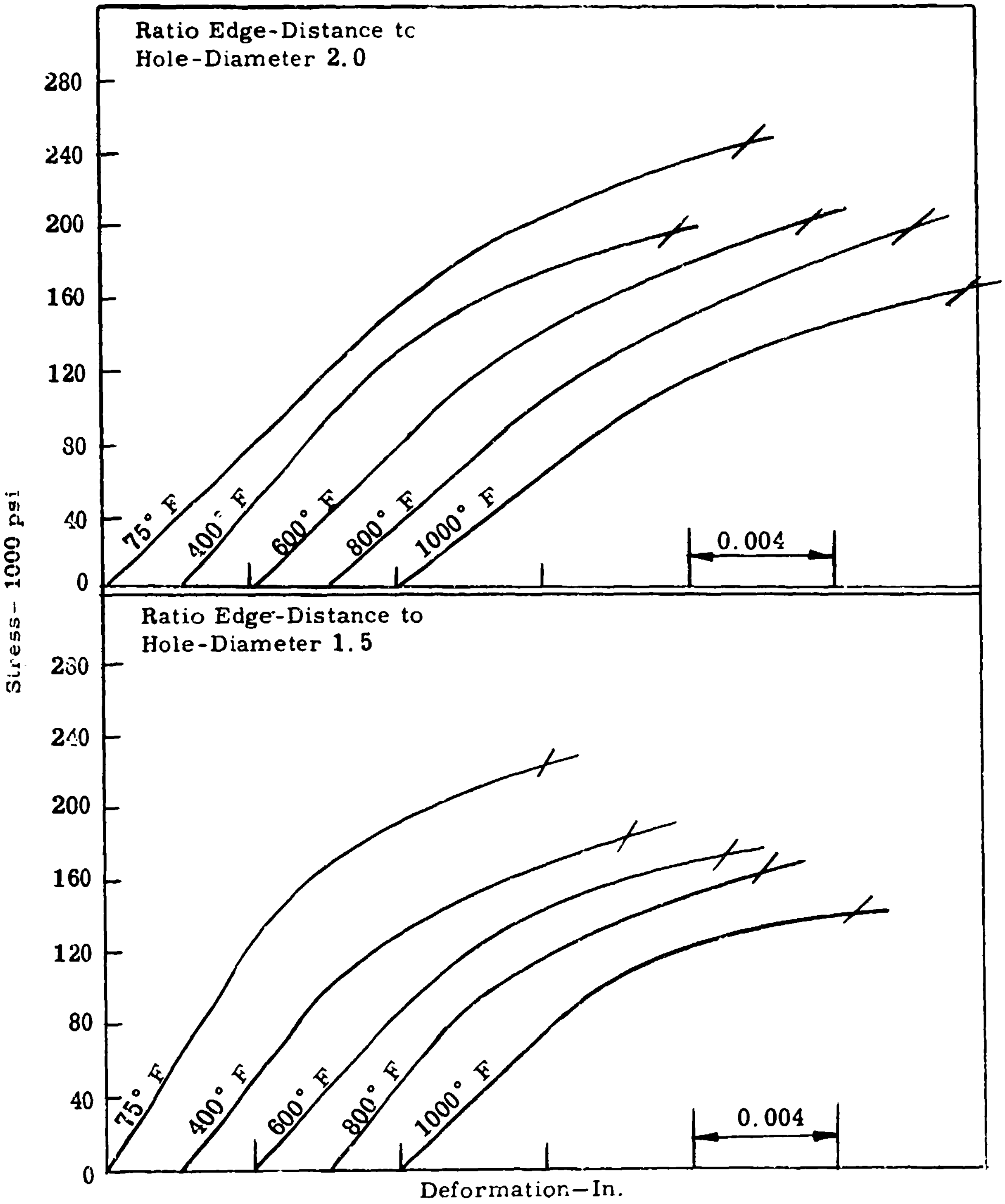


Fig. 111. Bearing stress-deformation curves for quenched and tempered Type 422 stainless steel sheet at various temperatures and one-half-hour exposure time.

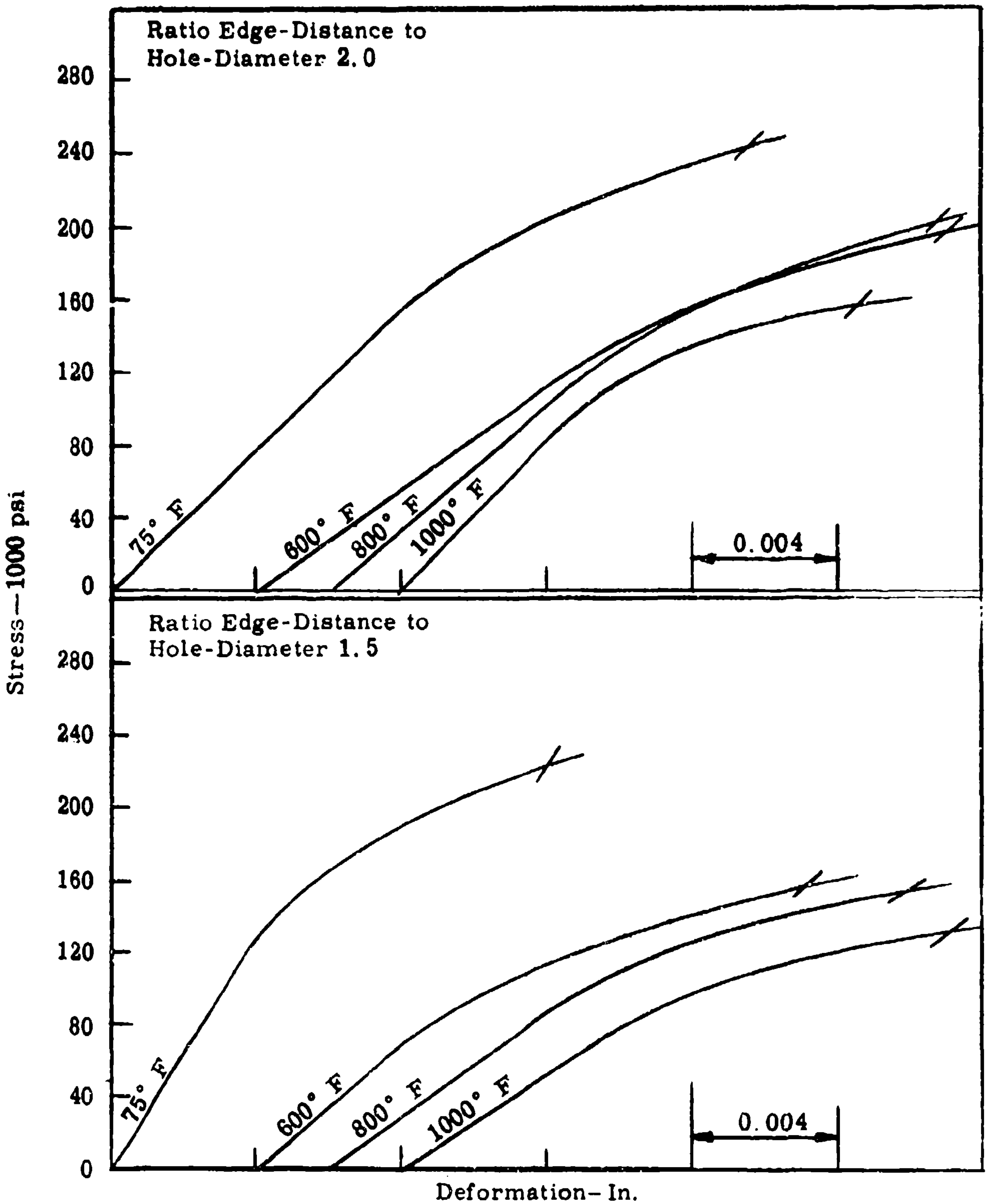


Fig. 112. Bearing stress-deformation curves for quenched and tempered Type 422 stainless steel sheet at various temperatures and ten-hour exposure time.

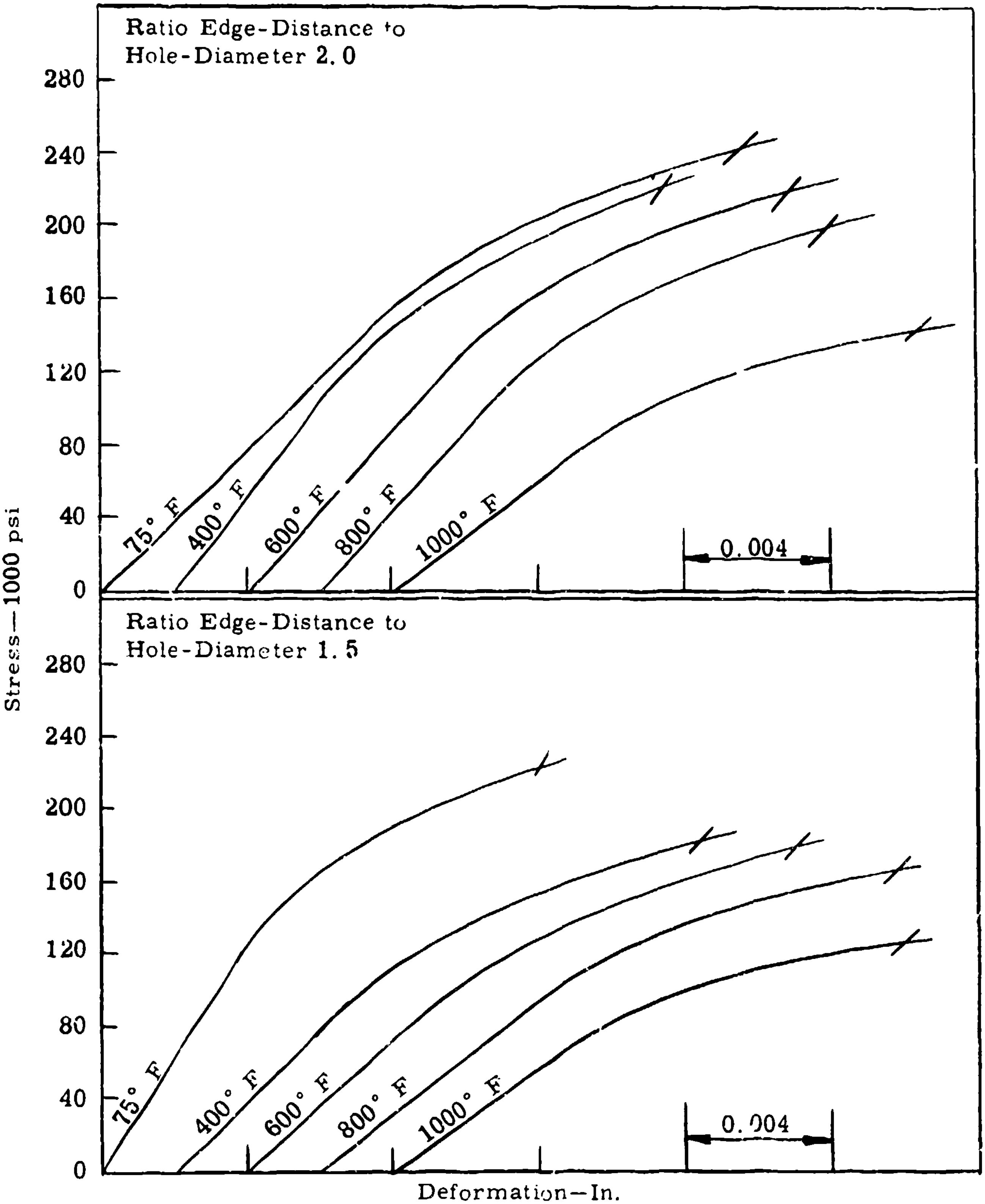


Fig. 113. Bearing stress-deformation curves for quenched and tempered Type 422 stainless steel sheet at various temperatures and one-hundred-hour exposure time.

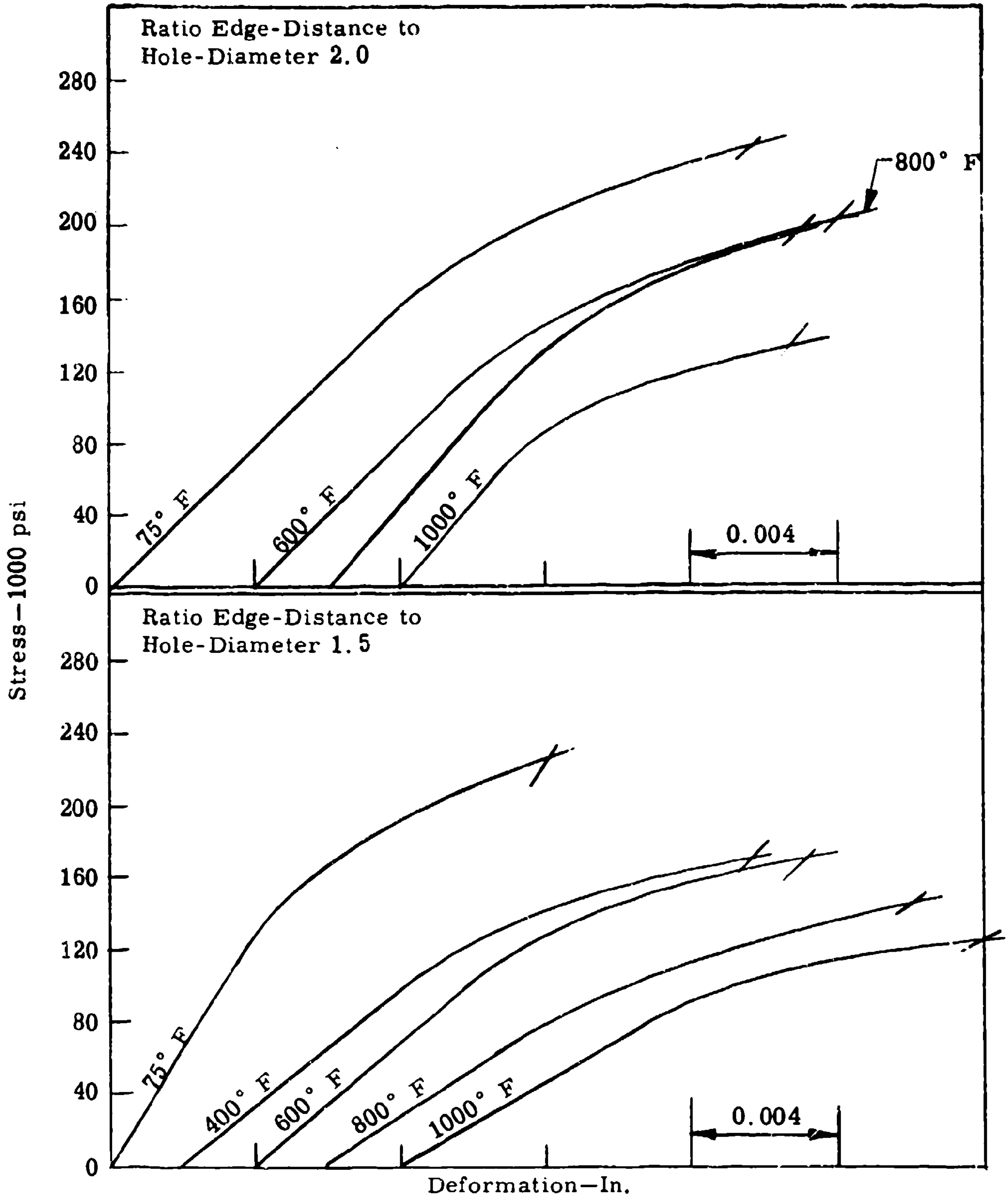


Fig. 114. Bearing stress-deformation curves for quenched and tempered Type 422 stainless steel sheet at various temperatures and one-thousand-hour exposure time.

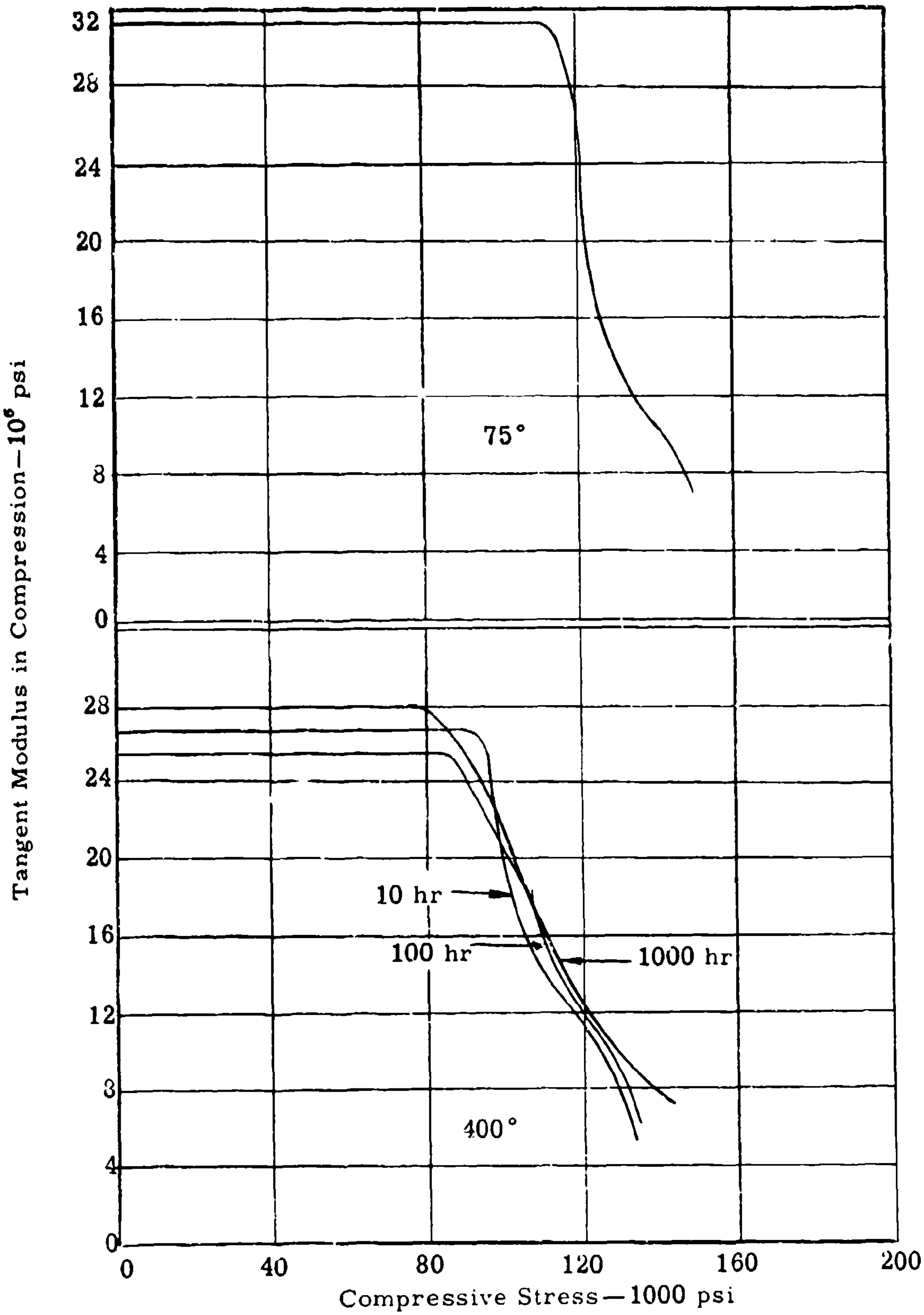


Fig. 115. Tangent-modulus vs. compressive-stress curves for quenched and tempered Type 422 stainless steel sheet at 75° F and 400° F and different exposure times.

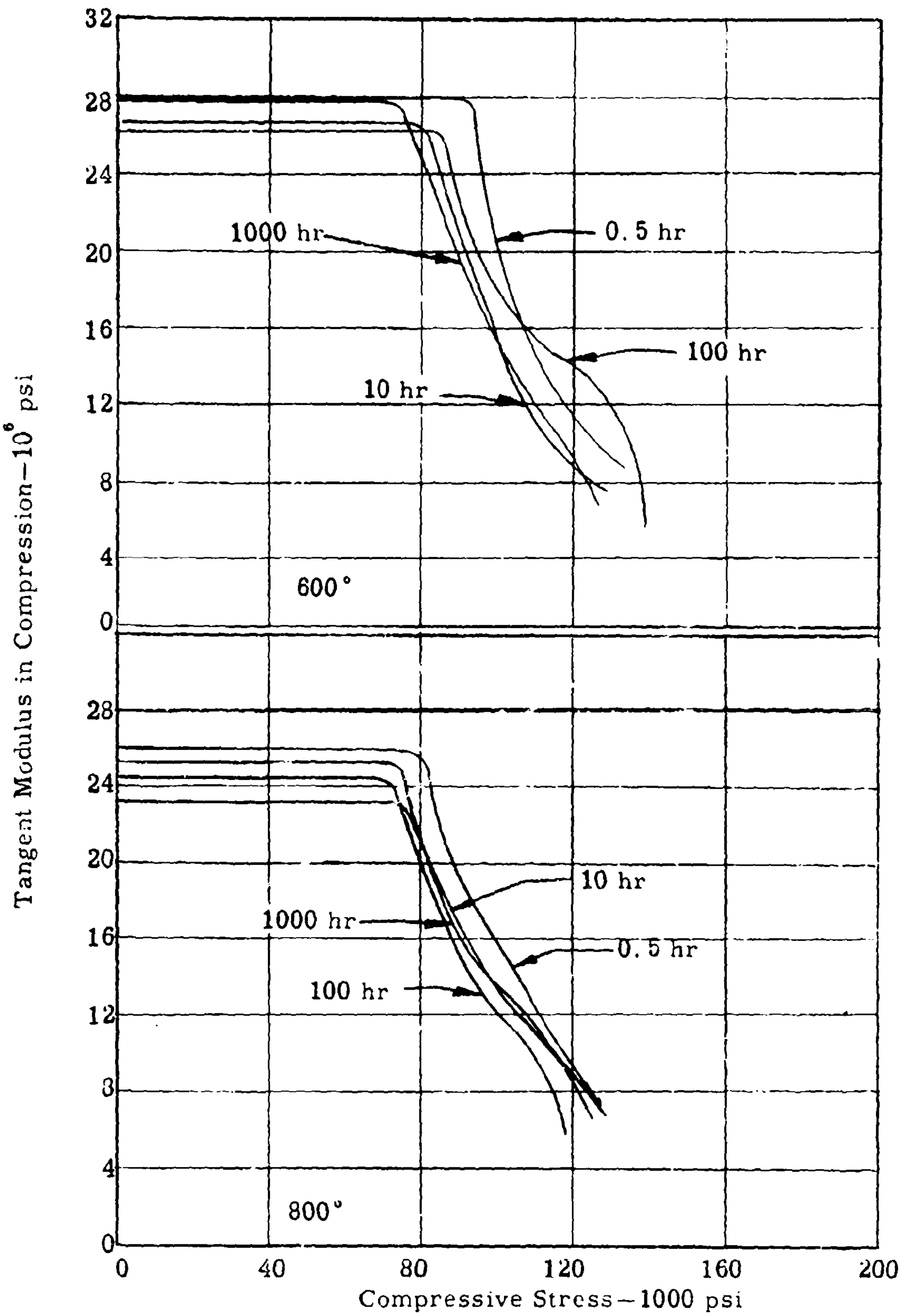


Fig. 116. Tangent-modulus vs. compressive-stress curves for quenched and tempered Type 422 stainless steel sheet at 600° F and 800° F and different exposure times.

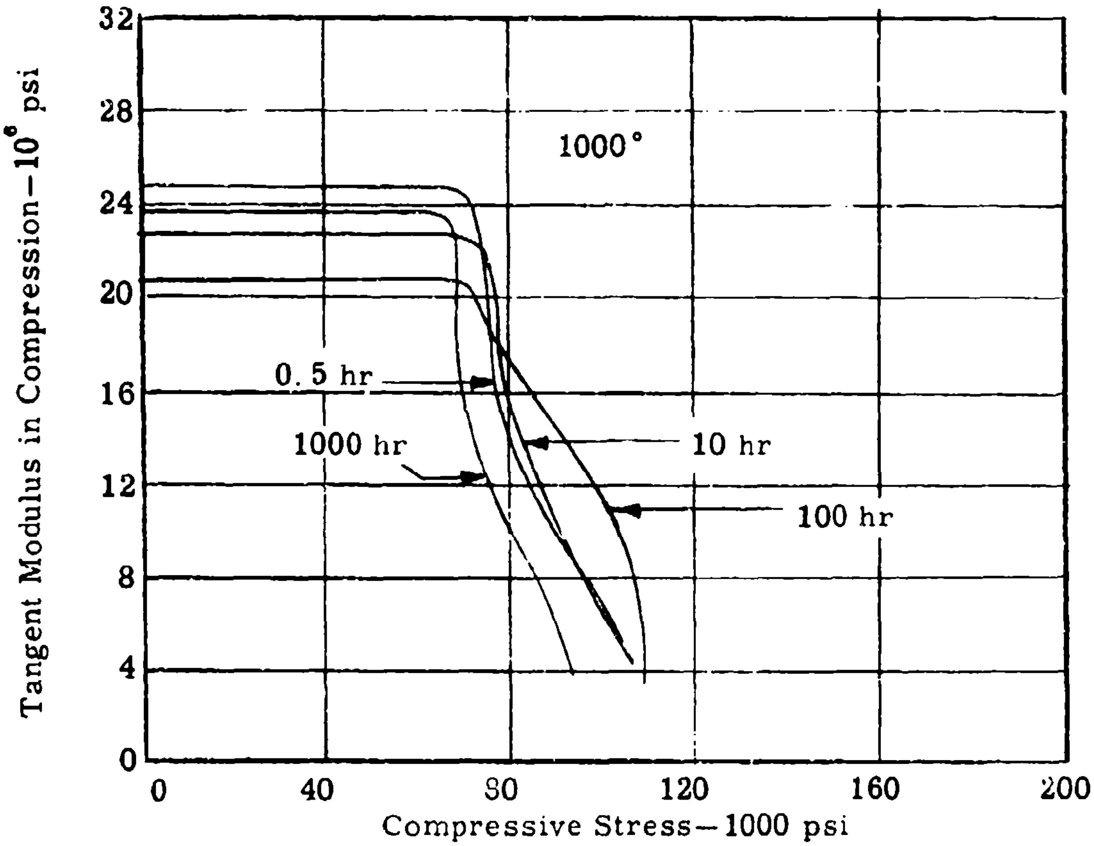


Fig. 117. Tangent-modulus vs. compressive-stress curves for quenched and tempered Type 422 stainless steel sheet at 1000° F and different exposure times.

Table 28

Tensile Properties of 0.062-In. Type 422 Stainless Steel Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| RT | | 130.2 | 162.0 | 30.6 | 6 | 35 | 119.0 | 201.0 |
| | | 139.5 | 160.0 | 30.0 | 5 | 35 | 118.5 | 206.0 |
| | | 145.0 | 154.0 | 30.3 | 9 | 36 | 117.0 | 204.0 |
| Avg | | 138.2 | 158.7 | 30.3 | 7 | 35 | 118.2 | 203.7 |
| 400 | 0.5 | 122.0 | 143.4 | 28.4 | 5 | 36 | 105.5 | 182.5 |
| | | 128.0 | 147.0 | 27.7 | 6 | 37 | 110.0 | 195.5 |
| | | 132.0 | 151.0 | 29.6 | 6 | 37 | 116.5 | 200.5 |
| Avg | | 127.3 | 147.1 | 28.5 | 6 | 37 | 110.6 | 192.8 |
| 400 | 10 | | 145.0 | | | | | |
| | | | 142.0 | | | | | |
| | | | 137.0 | | | | | |
| Avg | | | 141.3 | | | | | |
| 400 | 100 | 113.5 | 140.0 | 23.4 | 6 | 32 | 111.0 | 216.0 |
| | | 116.4 | 141.0 | 25.7 | 6 | 33 | 107.0 | 201.0 |
| | | 117.5 | 143.5 | 26.0 | 6 | 33 | 108.3 | 232.5 |
| Avg | | 115.8 | 141.5 | 25.0 | 6 | 33 | 108.7 | 216.5 |
| 400 | 1000 | 111.6 | 138.6 | 24.3 | 7 | 35 | 104.4 | 215.0 |
| | | 119.3 | 143.6 | 25.6 | 7 | 35 | 106.8 | 214.0 |
| | | 129.5 | 147.5 | 25.8 | 7 | 35 | 117.0 | 269.0 |
| Avg | | 120.1 | 143.2 | 25.2 | 7 | 35 | 109.4 | 232.6 |

Table 28 (continued)

Tensile Properties of 0.062-In. Type 422 Stainless Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 600 | 0.5 | 113.5 | 138.0 | 30.3 | 6 | 40 | 110.5 | 309.0 |
| | | 109.5 | 139.5 | 25.6 | 5 | 42 | 109.5 | 298.0 |
| | | 111.9 | 139.5 | 25.6 | 6 | 41 | 118.0 | 276.0 |
| Avg | | 111.6 | 139.0 | 27.2 | 6 | 41 | 112.7 | 294.3 |
| 600 | 10 | 105.0 | 137.0 | 29.0 | 5 | 35 | 112.0 | 197.5 |
| | | 120.0 | 141.0 | – | 7 | 38 | 111.9 | 300.0 |
| | | 112.0 | 137.0 | 27.7 | 5 | 40 | 108.5 | 210.0 |
| Avg | | 112.3 | 138.3 | 28.3 | 6 | 38 | 110.8 | 235.8 |
| 600 | 100 | 111.2 | 138.0 | 24.5 | 5 | 35 | 104.5 | 228.0 |
| | | 106.2 | 138.8 | 31.6 | 5 | 38 | 113.5 | 247.0 |
| | | 101.0 | 139.0 | 25.3 | 5 | 35 | 114.0 | 242.0 |
| Avg | | 106.3 | 138.6 | 27.1 | 5 | 36 | 110.7 | 239.0 |
| 600 | 1000 | 115.0 | 138.5 | 25.4 | 5 | 36 | 115.8 | 188.6 |
| | | 118.2 | 144.0 | 24.5 | 6 | 35 | 111.2 | 254.5 |
| | | 111.5 | 140.0 | 24.3 | 4 | 38 | 117.0 | 229.0 |
| Avg | | 114.9 | 140.1 | 24.7 | 5 | 36 | 114.7 | 224.0 |
| 800 | 0.5 | 113.0 | 133.0 | 23.0 | 8 | 35 | 103.0 | 215.0 |
| | | 102.5 | 130.0 | 23.4 | 8 | 36 | 94.6 | 189.5 |
| | | 102.0 | 132.0 | 24.5 | 8 | 36 | 97.6 | 192.0 |
| Avg | | 105.8 | 131.7 | 23.6 | 8 | 36 | 98.4 | 198.8 |

Table 28 (continued)

Tensile Properties of 0.062-In. Type 422 Stainless Steel Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 800 | 10 | 101.0 | 131.0 | 25.6 | 7 | 36 | 101.0 | 244.0 |
| | | 102.0 | 131.5 | 23.9 | 7 | 35 | 100.3 | 179.0 |
| | | 94.5 | 130.5 | 25.4 | 8 | 36 | 99.0 | 178.0 |
| Avg | | 99.2 | 131.0 | 25.0 | 7 | 36 | 100.1 | 200.3 |
| 800 | 100 | 102.5 | 130.5 | 26.8 | 7 | 38 | 102.5 | 228.0 |
| | | 105.8 | 133.0 | 23.1 | 7 | 40 | 105.8 | 203.0 |
| | | 102.0 | 130.0 | 24.7 | 7 | 40 | 99.0 | 229.0 |
| Avg | | 103.4 | 131.2 | 24.9 | 7 | 39 | 102.4 | 220.0 |
| 800 | 1000 | 108.0 | 127.0 | 27.3 | 5 | 38 | 100.5 | 153.0 |
| | | 102.0 | 127.5 | 21.7 | 6 | 37 | 97.5 | 177.0 |
| | | 105.0 | 129.0 | 22.5 | 7 | 37 | 97.5 | 178.0 |
| Avg | | 105.0 | 127.8 | 23.8 | 6 | 37 | 98.5 | 169.3 |
| 1000 | 0.5 | 95.0 | 101.0 | 19.8 | 13 | 36 | 67.3 | 140.0 |
| | | 88.5 | 105.0 | 22.2 | 12 | 37 | 64.0 | 135.0 |
| | | 87.0 | 104.0 | 23.9 | 10 | 36 | 64.0 | 116.0 |
| Avg | | 90.2 | 103.3 | 22.0 | 12 | 36 | 65.1 | 130.3 |
| 1000 | 10 | 86.2 | 98.2 | 27.5 | 11 | 39 | 69.6 | 151.5 |
| | | 84.2 | 97.0 | 28.6 | 9 | 37 | 60.5 | 129.5 |
| | | 84.7 | 100.0 | — | 10 | 37 | 61.8 | 135.0 |
| Avg | | 85.0 | 98.4 | 28.0 | 10 | 38 | 64.0 | 138.7 |

Table 28 (continued)

Tensile Properties of 0.062-In. Type 422 Stainless Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 1000 | 100 | 81.4 | 91.8 | 18.5 | 11 | 34 | 57.5 | 142.5 |
| | | 85.2 | 92.8 | 23.4 | 9 | 34 | 59.0 | 113.0 |
| | | 82.8 | 94.2 | 24.6 | 10 | 36 | 66.7 | 152.0 |
| Avg | | 83.1 | 92.9 | 22.2 | 10 | 35 | 61.1 | 135.8 |
| 1000 | 1000 | 79.8 | 85.5 | 26.3 | 14 | 34 | 62.9 | 136.0 |
| | | 81.7 | 90.7 | 26.3 | 17 | 35 | 62.5 | 134.5 |
| | | 87.5 | 100.5 | 28.1 | 12 | 35 | 77.7 | 147.5 |
| Avg | | 83.0 | 92.2 | 26.9 | 14 | 35 | 67.7 | 139.3 |

1. Hardness determinations made at room temperature after tests.
2. Rupture strength based on original cross section.
3. Rupture strength based on final cross section.
4. Heat treatment – 1900° F 15 min argon atmosphere, O.Q., [illegible] 2 hr.

Table 29

Tensile Strength of 3/16-In. Type 422 Stainless Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC |
| RT | | | | | | | 186.5 | 36 |
| | | | | | | | 185.5 | 32 |
| | | | | | | | 187.5 | 34 |
| Avg | | | | | | | 186.5 | 34 |
| 400 | 174.5 | 37 | 166.0 | 39 | 172.0 | 39 | 170.0 | 38 |
| | 173.5 | 36 | 169.0 | 39 | 168.5 | 40 | 169.5 | 38 |
| | 173.6 | 37 | 173.0 | 39 | 169.0 | 39 | 170.5 | 38 |
| Avg | 173.9 | 37 | 169.3 | 39 | 169.8 | 39 | 170.0 | 38 |
| 600 | 164.0 | 36 | 167.5 | 37 | 170.0 | 37 | 167.0 | 40 |
| | 167.0 | 36 | 167.0 | 37 | 170.0 | 36 | 169.0 | 38 |
| | 166.0 | 37 | 167.5 | 37 | 168.0 | 37 | 168.0 | 39 |
| | 166.0 | 37 | 167.5 | 37 | 173.0 | 37 | — | — |
| Avg | 165.8 | 36 | 167.4 | 37 | 170.2 | 37 | 168.0 | 39 |
| 800 | 145.0 | 37 | 151.0 | 37 | 151.0 | 37 | 150.2 | 38 |
| | 154.0 | 38 | 153.0 | 37 | 152.5 | 37 | 153.0 | 37 |
| | 155.5 | 37 | 151.0 | 37 | 151.5 | 38 | 152.0 | 38 |
| | 153.8 | 37 | 151.5 | 37 | 153.0 | 38 | — | — |
| Avg | 152.1 | 37 | 151.6 | 37 | 152.0 | 38 | 151.7 | 38 |

Table 29 (continued)

Tensile Strength of 3/16-In. Type 422 Stainless Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC |
| 1000 | 115.0 | 40 | 113.4 | 38 | 100.5 | 39 | 97.00 | 36 |
| | 111.2 | 36 | 112.3 | 37 | 104.0 | 38 | 94.00 | 37 |
| | 111.2 | 38 | 112.2 | 38 | 102.5 | 36 | 99.00 | 37 |
| Avg | 112.5 | 38 | 113.3 | 38 | 102.3 | 38 | 96.67 | 37 |

1. Ultimate tensile strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment — 1900° F 15 min argon atmosphere, O. Q., 1000° F 2 hr, A. C.

## Table 30

Compressive Properties of 0.062-In. Type 422 Stainless Steel[3] Sheet at Different Temperatures and Holding Times

| Hold Time, hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | CYS[1] 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| RT | | | | | | | | | | 149.0 | 31.3 | 38 |
| | | | | | | | | | | 146.8 | 31.0 | 36 |
| | | | | | | | | | | 154.0 | 32.9 | 37 |
| Avg | | | | | | | | | | 149.9 | 31.7 | 37 |
| 400 | 125.0 | 26.5 | 38 | 136.8 | 25.1 | 36 | 135.0 | 27.9 | 39 | 138.0 | 26.3 | 37 |
| | 130.0 | 26.9 | 37 | 133.5 | 24.2 | 34 | 135.5 | 27.8 | 38 | 143.0 | 21.2 | 38 |
| | 121.5 | 27.7 | 36 | 134.5 | 26.7 | 35 | 140.0 | 26.5 | 38 | 141.0 | 25.5 | 37 |
| Avg | 125.5 | 27.0 | 37 | 134.9 | 25.3 | 35 | 136.8 | 27.4 | 38 | 140.7 | 24.3 | 37 |
| 600 | 133.0 | 27.9 | 39 | 128.0 | 27.5 | 38 | 131.5 | 29.2 | 37 | 130.0 | 24.1 | 38 |
| | 131.0 | 28.1 | 38 | 128.5 | 26.7 | 38 | 138.0 | 24.2 | 37 | 125.5 | 27.8 | 38 |
| | 140.0 | 27.4 | 39 | 132.0 | 26.5 | 37 | 138.0 | 26.2 | 37 | 133.5 | 28.2 | 38 |
| Avg | 134.7 | 27.8 | 39 | 129.5 | 26.9 | 38 | 135.8 | 26.5 | 37 | 129.7 | 26.7 | 38 |
| 800 | 127.4 | 25.9 | 38 | 125.2 | 26.1 | 37 | 118.5 | 24.5 | 40 | 125.0 | 25.2 | 38 |
| | 126.3 | 25.0 | 38 | 126.0 | 20.7 | 36 | 130.5 | 20.6 | 40 | 129.0 | 24.0 | 40 |
| | 129.5 | 24.2 | 37 | 128.0 | 23.3 | 38 | 127.5 | 26.8 | 40 | 124.0 | 25.5 | 40 |
| Avg | 127.7 | 25.0 | 38 | 126.4 | 23.4 | 37 | 125.5 | 24.0 | 40 | 126.0 | 24.9 | 39 |

Table 30 (continued)

Compressive Properties of 0.062-In. Type 422 Stainless Steel[3] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | CYS[1] 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| 1000 | 96.2 | 24.1 | 34 | 107.0 | 20.1 | 37 | 109.0 | 20.8 | 37 | 88.2 | 24.3 | 36 |
| | 104.2 | 24.6 | 35 | 106.0 | 22.7 | 37 | 100.0 | 16.8 | 38 | 93.5 | 23.7 | 34 |
| | 102.2 | 22.2 | 37 | 111.0 | 25.6 | 37 | 101.5 | 25.0 | 37 | 91.3 | 20.3 | 36 |
| Avg | 100.9 | 23.6 | 35 | 108.0 | 22.8 | 37 | 103.8 | 20.9 | 37 | 91.0 | 22.8 | 35 |

1. Compressive yield strength
2. Hardness determinations made at room temperature after tests.
3. Heat treatment — 1900° F 15 min argon atmosphere, O.Q., 1000° F 2 hr, A. C.

## Table 31

### Shear Strength of 3/16-In. Type 422 Stainless Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | USS[1] 1000 psi | Hard[2] RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC |
| RT | | | | | | | 118.0 | 39 |
| | | | | | | | 115.0 | 37 |
| | | | | | | | 113.0 | 36 |
| Avg | | | | | | | 115.3 | 37 |
| 400 | 98.8 | 33 | | | 100.1 | 36 | 102.5 | 32 |
| | 99.2 | 33 | | | 102.5 | 37 | 99.5 | 33 |
| | 103.0 | 35 | | | 99.5 | 36 | 101.0 | 35 |
| | 100.3 | 34 | | | 101.0 | 36 | 101.0 | 34 |
| 600 | 99.50 | 34 | 101.0 | 36 | 98.25 | 29 | 103.5 | 39 |
| | 98.80 | 34 | 101.5 | 36 | 97.00 | 29 | 98.8 | 33 |
| | 99.20 | 34 | 100.5 | 36 | 100.5 | 30 | 102.0 | 34 |
| | - | - | 100.5 | 36 | 100.0 | 29 | - | - |
| Avg | 99.17 | 34 | 100.9 | 36 | 98.93 | 29 | 101.4 | 35 |
| 800 | 95.50 | 35 | 94.00 | 34 | 94.40 | 36 | 92.30 | 37 |
| | 95.50 | 36 | 94.00 | 34 | 94.40 | 36 | 98.70 | 31 |
| | 93.50 | 35 | 94.50 | 34 | 94.40 | 36 | 95.40 | 37 |
| Avg | 94.83 | 35 | 94.17 | 34 | 94.40 | 36 | 95.50 | 35 |

Table 31 (continued)

Shear Strength of 3/16-In. Type 422 Stainless Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | USS[1] 1000 psi | Hard[2] RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC |
| 1000 | 77.70 | 35 | 75.70 | 37 | 82.20 | 34 | 75.00 | 31 |
| | 78.00 | 36 | 74.20 | 34 | 78.70 | 32 | 73.30 | 34 |
| | 77.30 | 36 | 76.80 | 37 | 81.40 | 35 | 73.50 | 33 |
| Avg | 77.67 | 36 | 75.57 | 36 | 80.77 | 34 | 73.93 | 33 |

1. Ultimate shear strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment – 1900° F 15 min argon atmosphere, O. Q., 1000 ° F, 2 hr, A. C.

Table 32

Bearing Properties[4] of 0.062-In. Type 422 Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] | UBS[2] | Hard[3] | BYS | UBS | Hard | BYS | UBS | Hard | BYS | UBS | Hard |
| | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N |
| RT | | | | | | | | | | 223.0 | 254.0 | 37 |
| | | | | | | | | | | 233.0 | 253.0 | 37 |
| | | | | | | | | | | 225.0 | 251.0 | 37 |
| Avg | | | | | | | | | | 227.0 | 252.7 | 37 |
| 400 | 186.0 | 232.0 | 38 | | | | 196.0 | 227.0 | 39 | 162.0 | 221.0 | 37 |
| | 203.0 | 226.0 | 38 | | | | 200.0 | 234.0 | 38 | 171.5 | 229.0 | 37 |
| | 209.0 | 229.0 | 37 | | | | 183.0 | 229.0 | 39 | 171.0 | 221.0 | 37 |
| Avg | 199.3 | 229.0 | 38 | | | | 193.0 | 230.0 | 39 | 168.2 | 223.7 | 37 |
| 600 | 174.0 | 215.0 | 39 | 158.0 | 211.0 | 38 | 171.0 | 231.0 | 38 | 170.0 | 217.0 | 39 |
| | 177.0 | 218.0 | 40 | 191.0 | 209.0 | 39 | 180.0 | 229.0 | 39 | 170.0 | 219.0 | 40 |
| | 186.0 | 215.0 | 39 | – | 214.0 | 39 | 194.0 | 224.0 | 38 | 169.0 | 217.0 | 39 |
| Avg | 179.0 | 216.0 | 39 | 174.5 | 211.3 | 39 | 181.7 | 228.0 | 38 | 169.7 | 217.7 | 39 |
| 800 | 144.5 | 212.0 | 40 | 155.5 | 213.0 | 37 | 179.0 | 230.0 | 39 | 145.5 | 202.0 | 39 |
| | 165.0 | 212.0 | 38 | 164.0 | 209.0 | 39 | 162.0 | 223.0 | 38 | 151.0 | 207.0 | 37 |
| | – | 212.0 | 39 | 156.0 | 212.0 | 39 | 160.7 | 220.0 | 38 | – | 209.0 | 39 |
| Avg | 154.7 | 212.0 | 39 | 161.8 | 211.3 | 38 | 167.2 | 224.3 | 38 | 148.2 | 206.0 | 38 |

Table 32 (continued)

Bearing Properties[4] of 0.062-In. Type 422 Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] | UBS[2] | Hard[3] | BYS | UBS | Hard | BYS | UBS | Hard | BYS | UBS | Hard |
| | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N |
| 1000 | 141.0 | 156.0 | 36 | 134.0 | 159.0 | 38 | 126.0 | 150.0 | 38 | 124.0 | 142.8 | 35 |
| | 137.0 | 164.0 | 38 | 132.0 | 159.0 | 38 | 130.5 | 153.0 | 38 | 122.0 | 142.0 | 35 |
| | 141.0 | 153.0 | 36 | 138.0 | 158.5 | 38 | 123.3 | 152.5 | 38 | 123.0 | 140.0 | 36 |
| Avg | 139.7 | 157.7 | 37 | 134.7 | 158.8 | 38 | 126.6 | 151.8 | 38 | 123.0 | 141.6 | 35 |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge-distance to hole-diameter ratio 1.5
5. Heat treatment – 1900° F 15 min argon atmosphere, O.Q., 1000° F 2 hr, A. C.

Table 33

Bearing Properties[4] of 0.062-In. Type 422 Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] 1000 psi | UBS[2] 1000 psi | Hard[3] R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N |
| RT | | | | | | | | | | 241.0 | 330.0 | 38 |
| | | | | | | | | | | 256.0 | 331.0 | 36 |
| | | | | | | | | | | 242.0 | 328.0 | 38 |
| Avg | | | | | | | | | | 246.3 | 329.7 | 37 |
| 400 | 197.0 | 285.0 | 37 | | | | 219.0 | 303.0 | 39 | 194.0 | 303.0 | 39 |
| | 194.0 | 285.0 | 37 | | | | 256.0 | 297.0 | 38 | 181.5 | 310.0 | 38 |
| | 206.0 | 285.0 | 37 | | | | 212.0 | 289.0 | 39 | 180.5 | 301.0 | 38 |
| Avg | 199.0 | 285.0 | 37 | | | | 229.0 | 296.3 | 39 | 185.3 | 304.7 | 38 |
| 600 | 203.0 | 285.0 | 36 | 191.0 | 297.0 | 39 | 220.5 | 279.0 | 37 | 194.0 | 284.0 | 39 |
| | -- | 283.0 | 35 | 197.0 | 300.0 | 38 | 236.0 | 279.0 | 38 | 210.0 | 273.0 | 40 |
| | 197.0 | 281.0 | 36 | 246.0 | 294.0 | 37 | 184.0 | 276.0 | 37 | 188.0 | 273.0 | 39 |
| Avg | 200.0 | 283.0 | 36 | 211.3 | 297.0 | 38 | 213.5 | 278.0 | 37 | 197.3 | 276.7 | 39 |
| 800 | 197.0 | 273.0 | 41 | 188.0 | 267.0 | 42 | 194.0 | 266.0 | 38 | 197.0 | 273.0 | 41 |
| | 190.0 | 266.0 | 43 | 202.0 | 282.0 | 38 | 201.5 | 269.0 | 39 | 206.0 | 270.0 | 40 |
| | 197.0 | 274.0 | 41 | 234.0 | 280.0 | 41 | 206.0 | 273.0 | 39 | 203.0 | 274.0 | 41 |
| Avg | 194.7 | 271.0 | 42 | 208.0 | 276.3 | 40 | 200.5 | 269.3 | 39 | 202.0 | 272.3 | 41 |

Table 33 (continued)

Bearing Properties[4] of 0.062-In. Type 422 Stainless Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] (1000 psi) | UBS[2] (1000 psi) | Hard[3] R45N | BYS (1000 psi) | UBS (1000 psi) | Hard R45N | BYS (1000 psi) | UBS (1000 psi) | Hard R45N | BYS (1000 psi) | UBS (1000 psi) | Hard R45N |
| 1000 | 164.0 | 202.0 | 35 | 158.0 | 200.0 | 38 | 154.0 | 194.0 | 38 | 139.5 | 174.0 | 36 |
| | 171.5 | 213.0 | 37 | 164.0 | 202.0 | 37 | 142.0 | 185.0 | 36 | 133.0 | 173.0 | 36 |
| | 157.0 | 215.0 | 37 | 153.0 | 193.0 | 37 | – | 189.0 | 37 | 133.0 | 173.0 | 38 |
| Avg | 164.0 | 210.0 | 36 | 158.3 | 198.3 | 37 | 148.0 | 189.3 | 37 | 35.0 | 173.3 | 37 |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge-distance to hole-diameter ratio 2.0.
5. Heat treatment – 1900° F 15 min argon atmosphere, O.Q., 1000° F 2 hr, A.C.

## 10.6 17-22 A (S) Alloy Steel Sheet, Quenched and Tempered

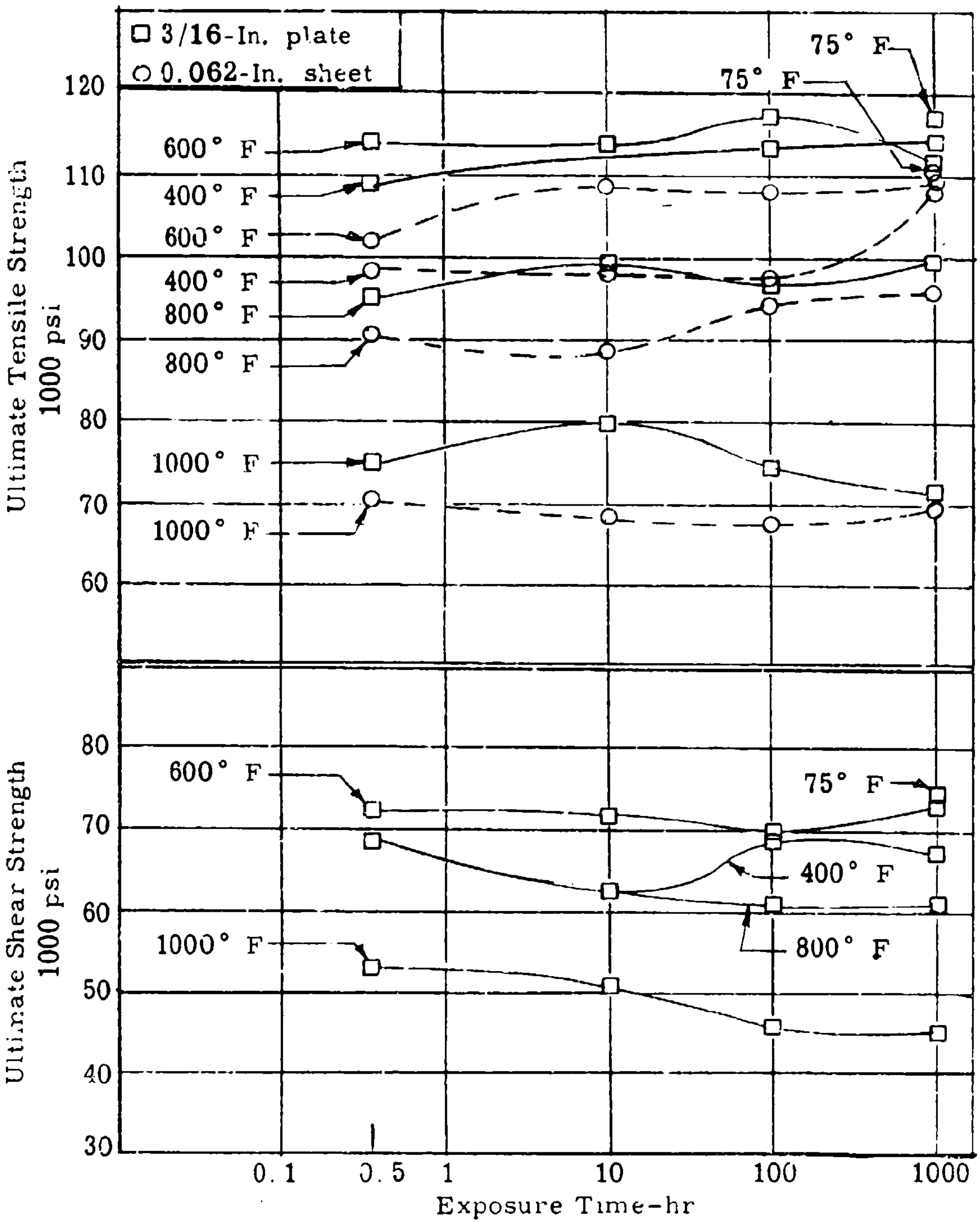


Fig. 118. Effect of exposure time on the ultimate tensile strength and ultimate shear strength of quenched and tempered 17-22 A (S) alloy steel at different temperatures.

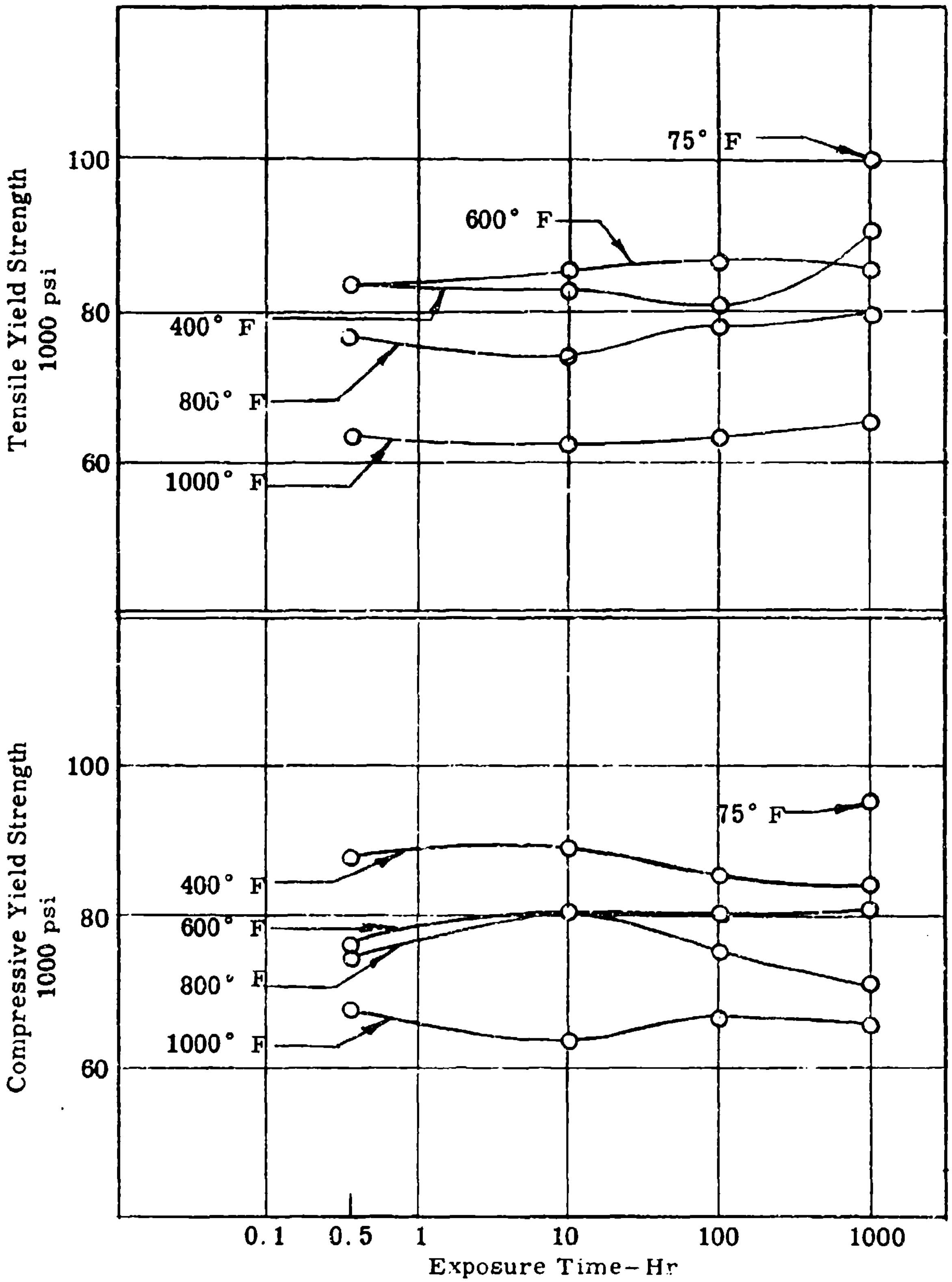


Fig. 119. Effect of exposure time on the tensile and compressive yield strength of quenched and tempered 17-22 A (S) alloy steel sheet at different temperatures.

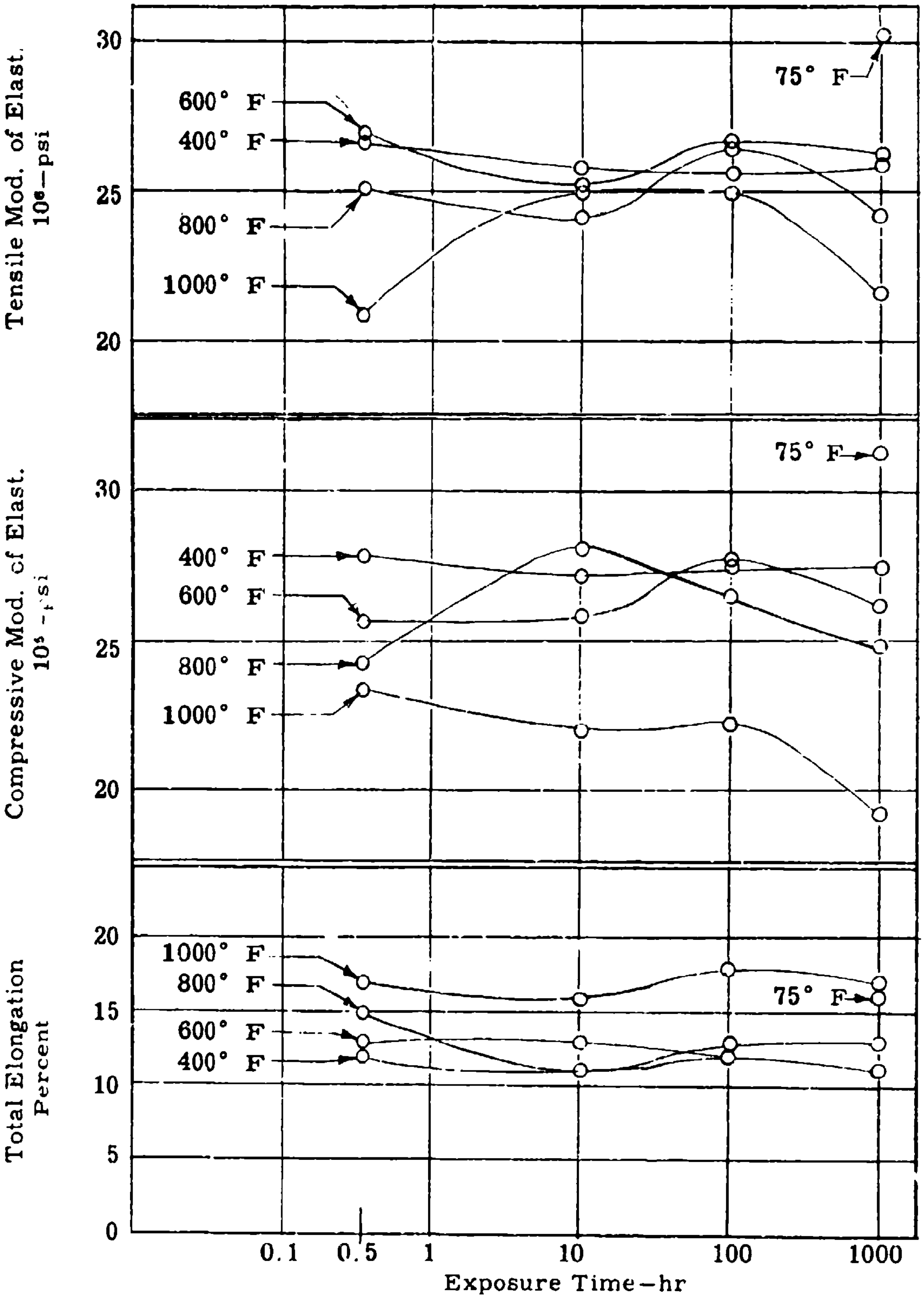


Fig. 12( Effect of exposure time on the tensile and compressive moduli of elasticity and percent elongation of quenched and tempered 17-22 A (S) alloy steel sheet at different temperatures.

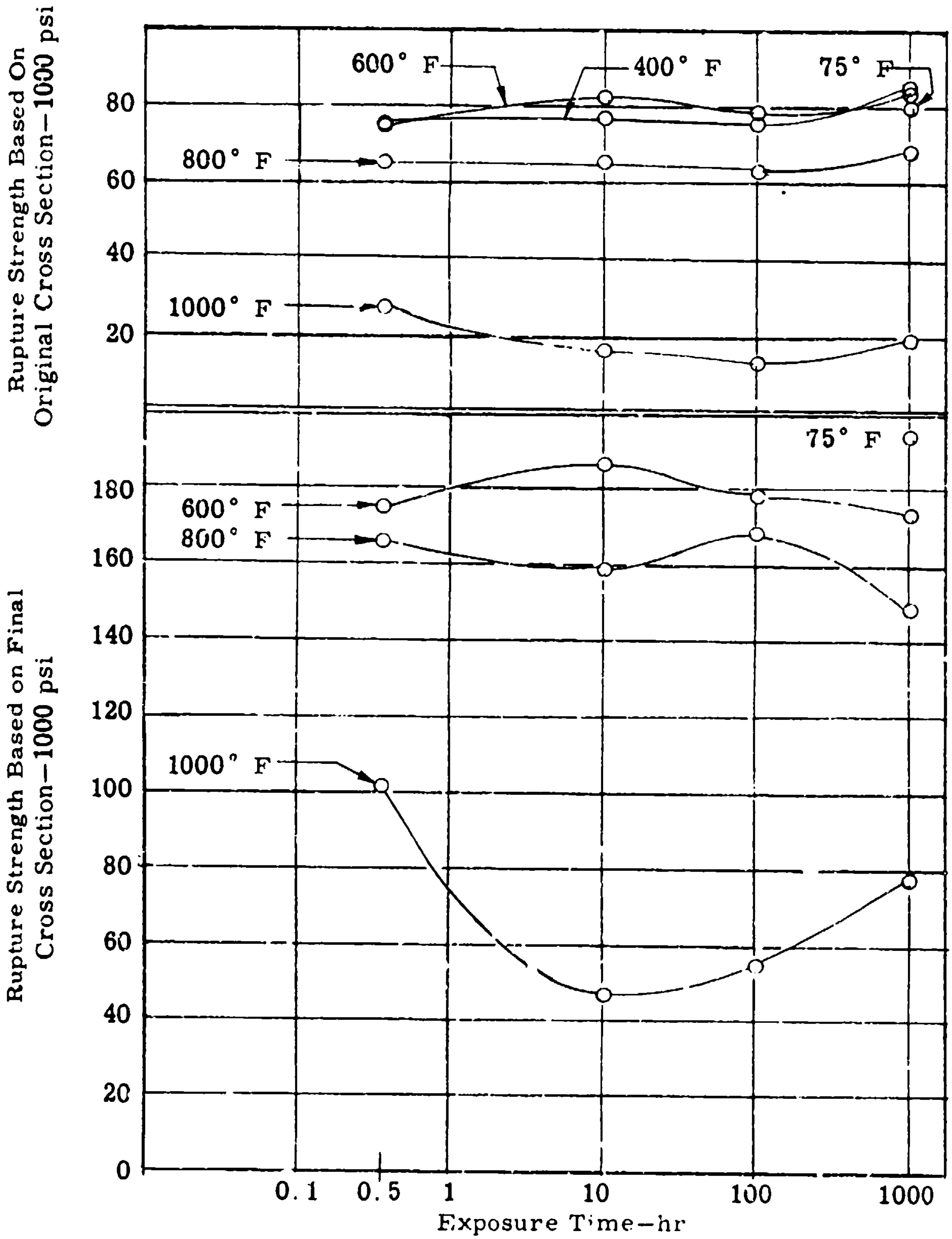


Fig. 121. Effect of exposure time on the tensile rupture strength of quenched and tempered 17-22 A (S) alloy steel sheet at different temperatures.

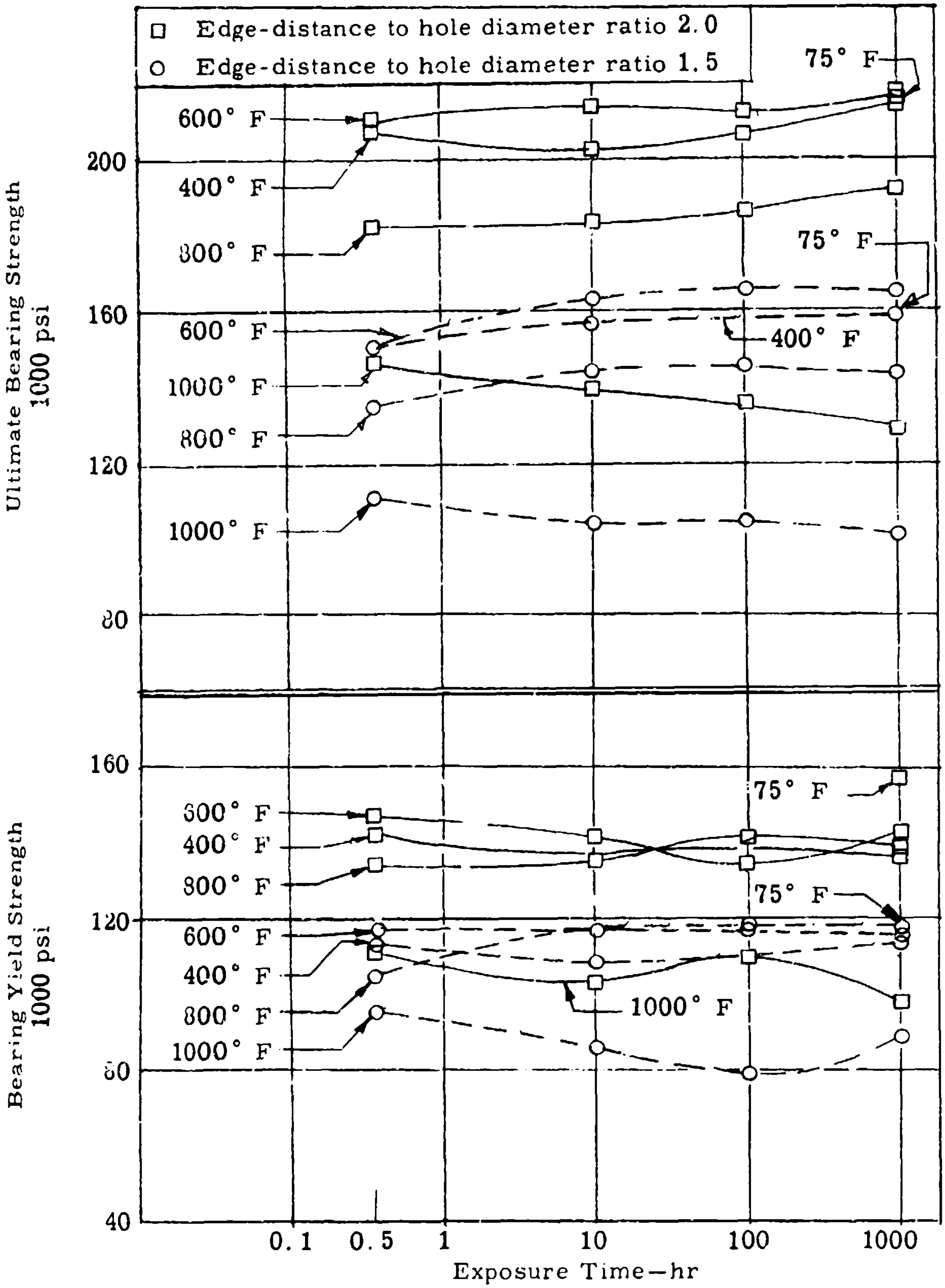


Fig. 122. Effect of exposure time on the bearing ultimate and yield strengths of quenched and tempered 17-22 A (S) alloy steel sheet at different temperatures.

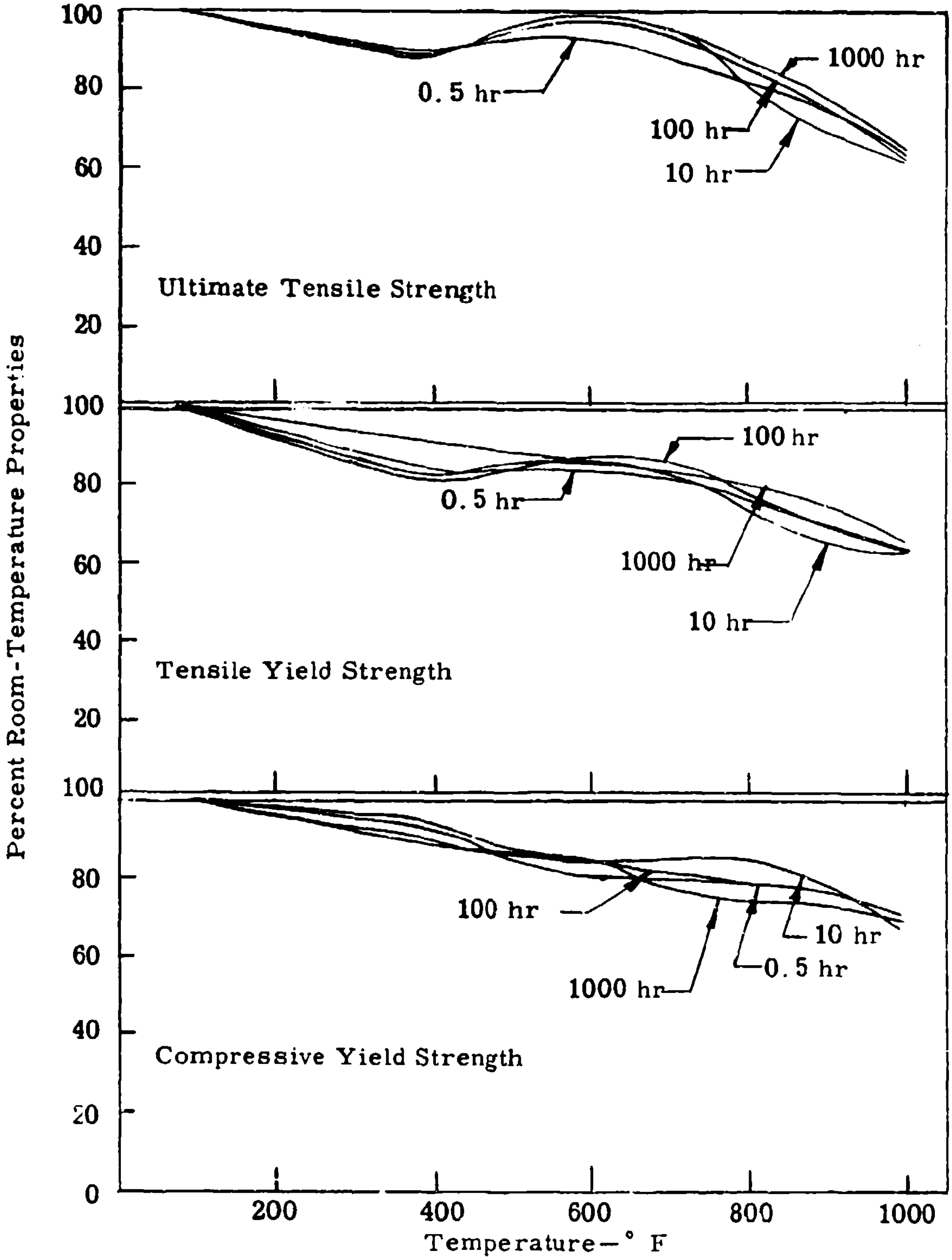


Fig. 123. Elevated-temperature strength properties as per cent of room-temperature properties for quenched and tempered 17-22 A (S) alloy steel sheet at different exposure times.

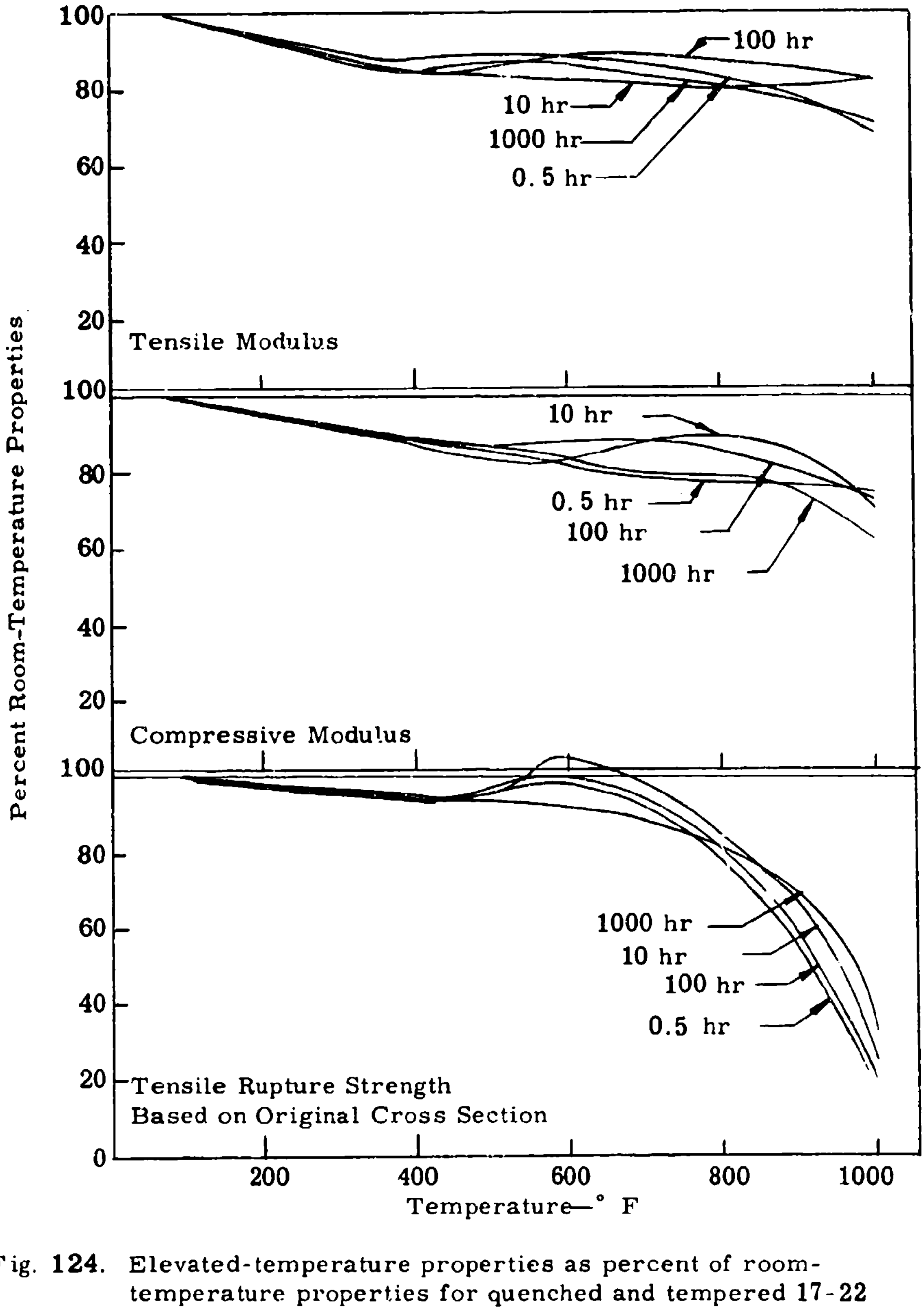


Fig. 124. Elevated-temperature properties as percent of room-temperature properties for quenched and tempered 17-22 A (S) alloy steel sheet at different exposure times.

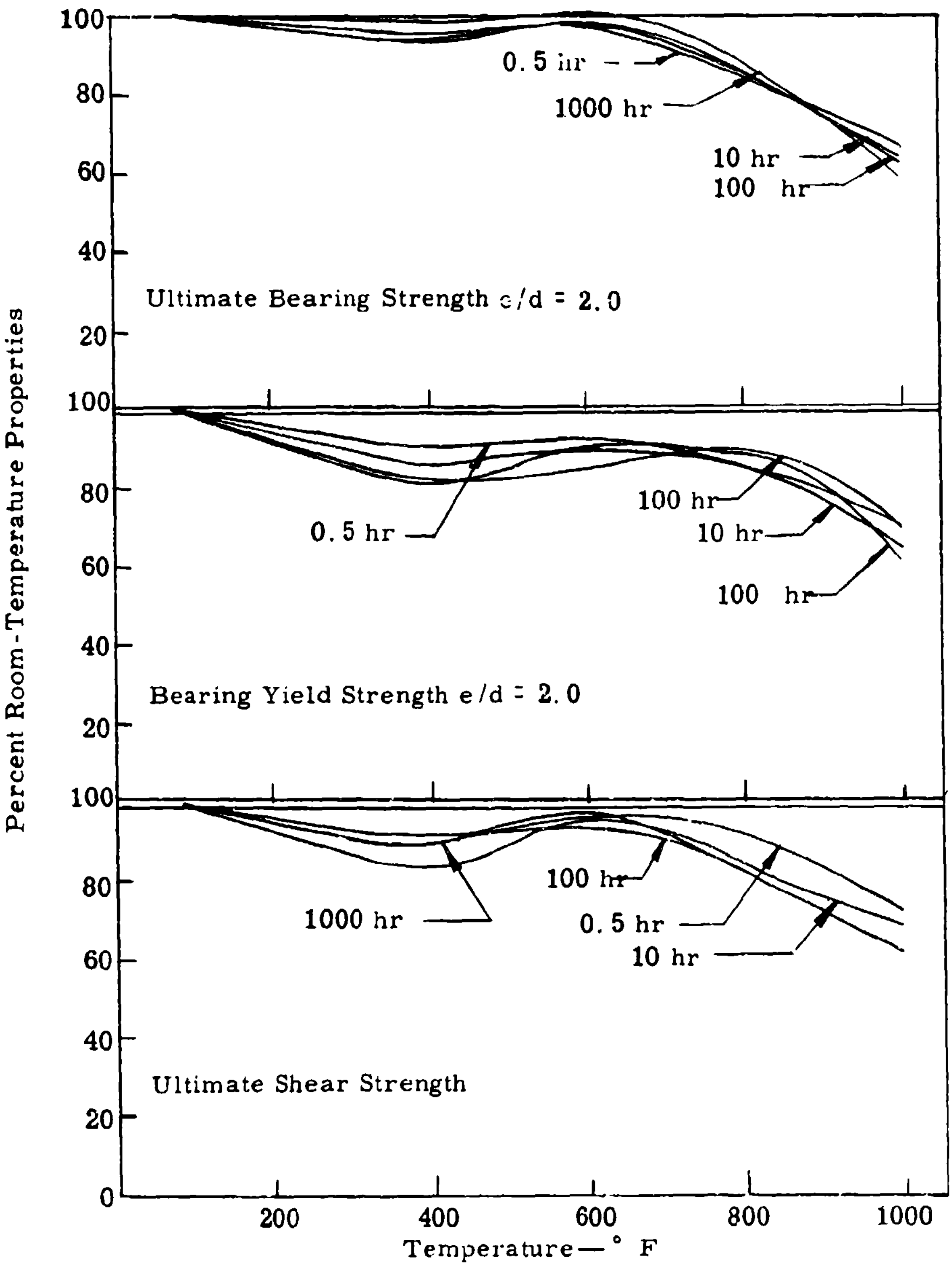


Fig. 125. Elevated-temperature strength properties as percent of room temperature properties for quenched and tempered 17-22 A (S) alloy steel sheet at different exposure times.

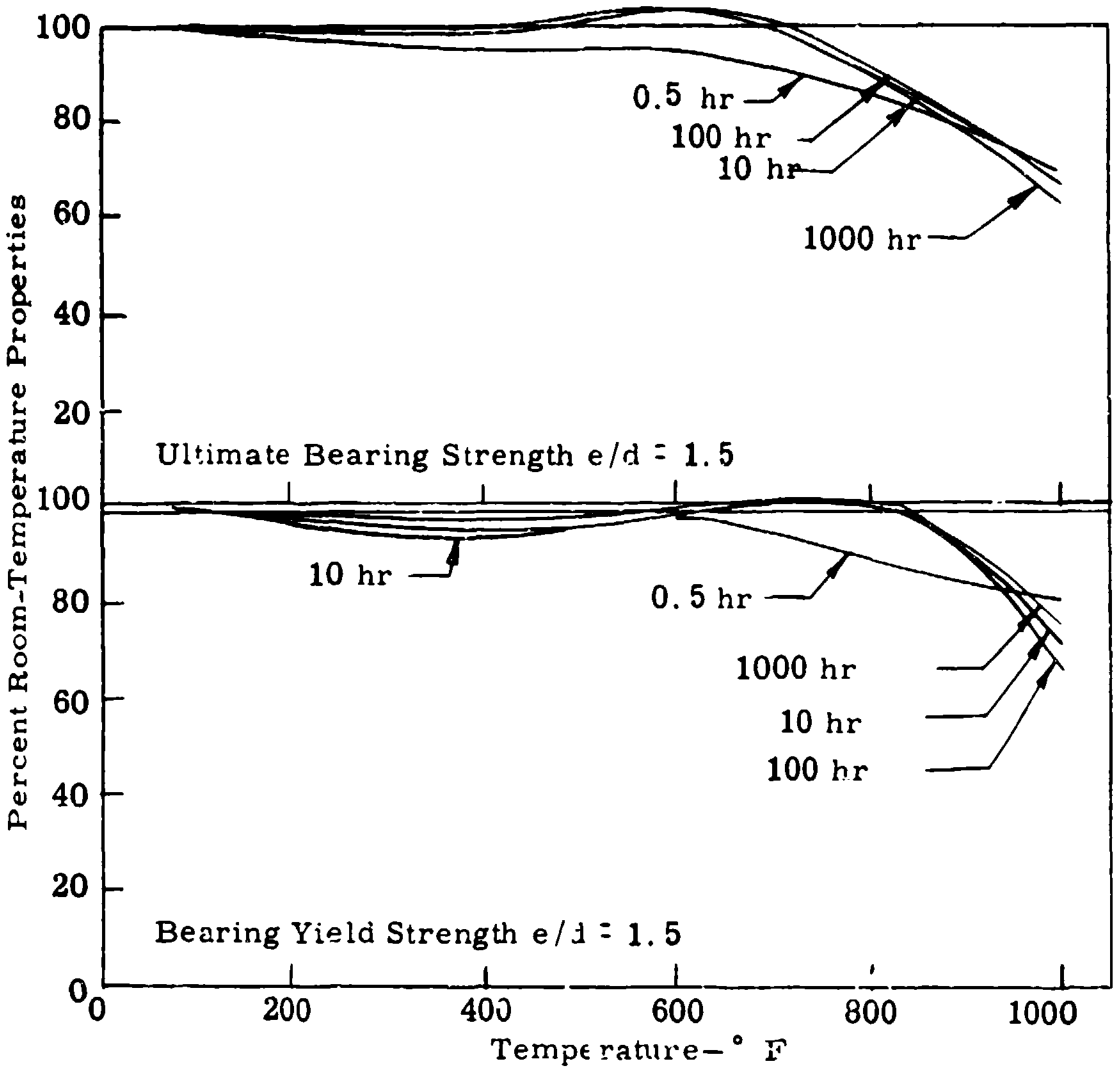


Fig. 126. Elevated-temperature strength properties as percent of room-temperature properties for quenched and tempered 17-22 A (S) alloy steel sheet at different exposure times.

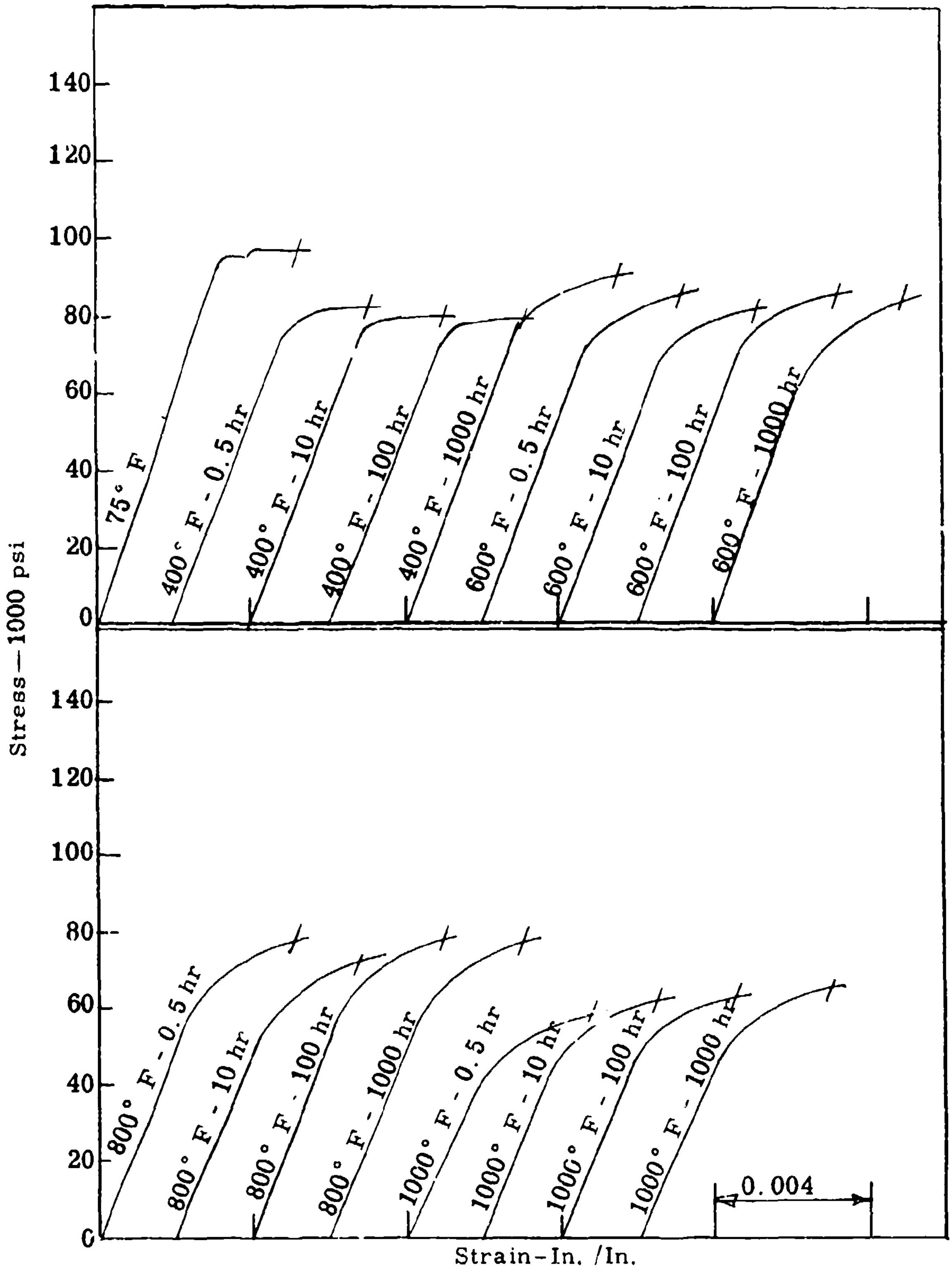


Fig. 127. Tensile stress-strain curves for quenched and tempered 17-22 A (S) alloy steel sheet at various temperatures and exposure times

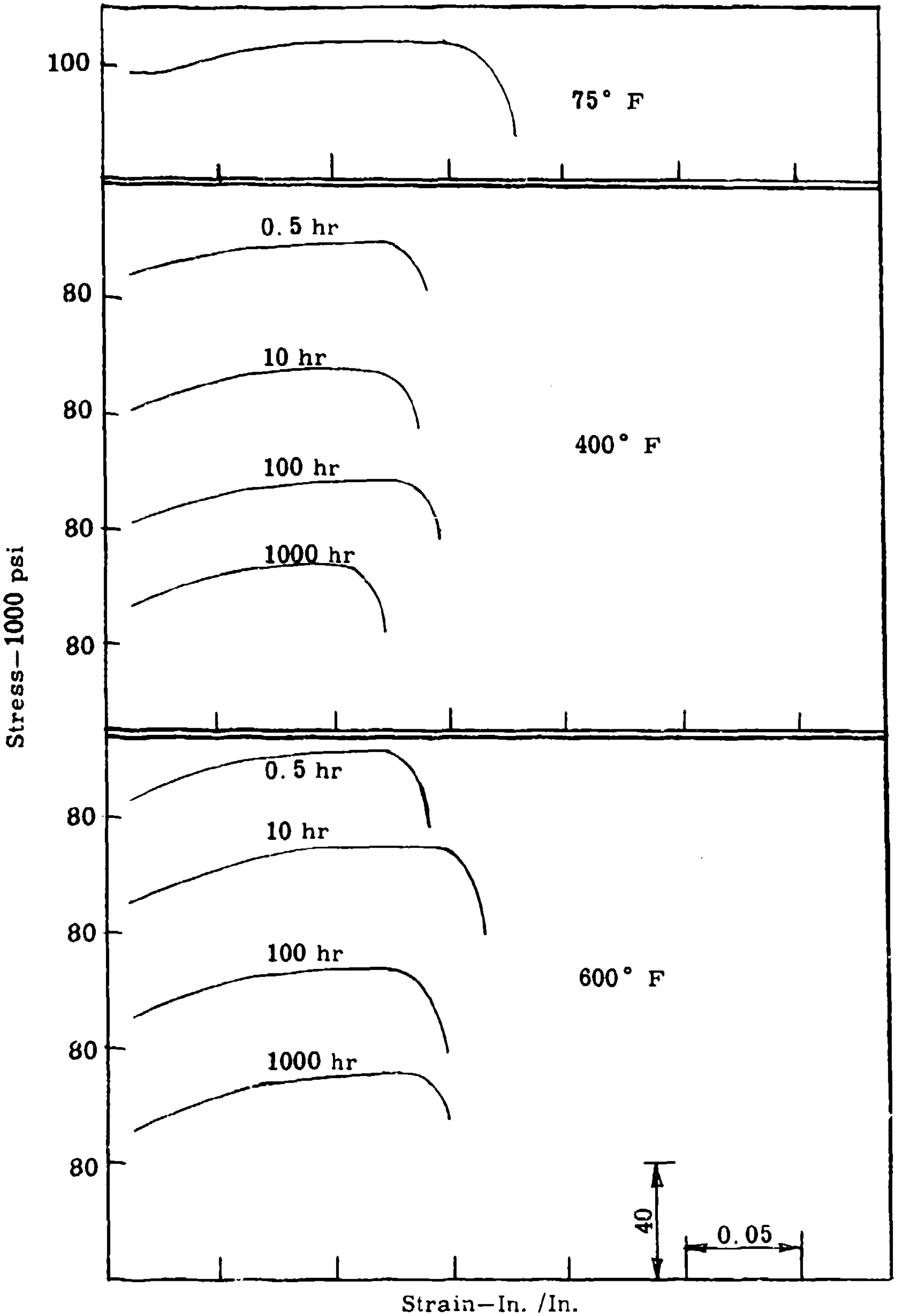


Fig. 128. Tensile postyield stress-strain curves for quenched and tempered 17-22 A (S) alloy steel sheet at various temperatures and exposure times.

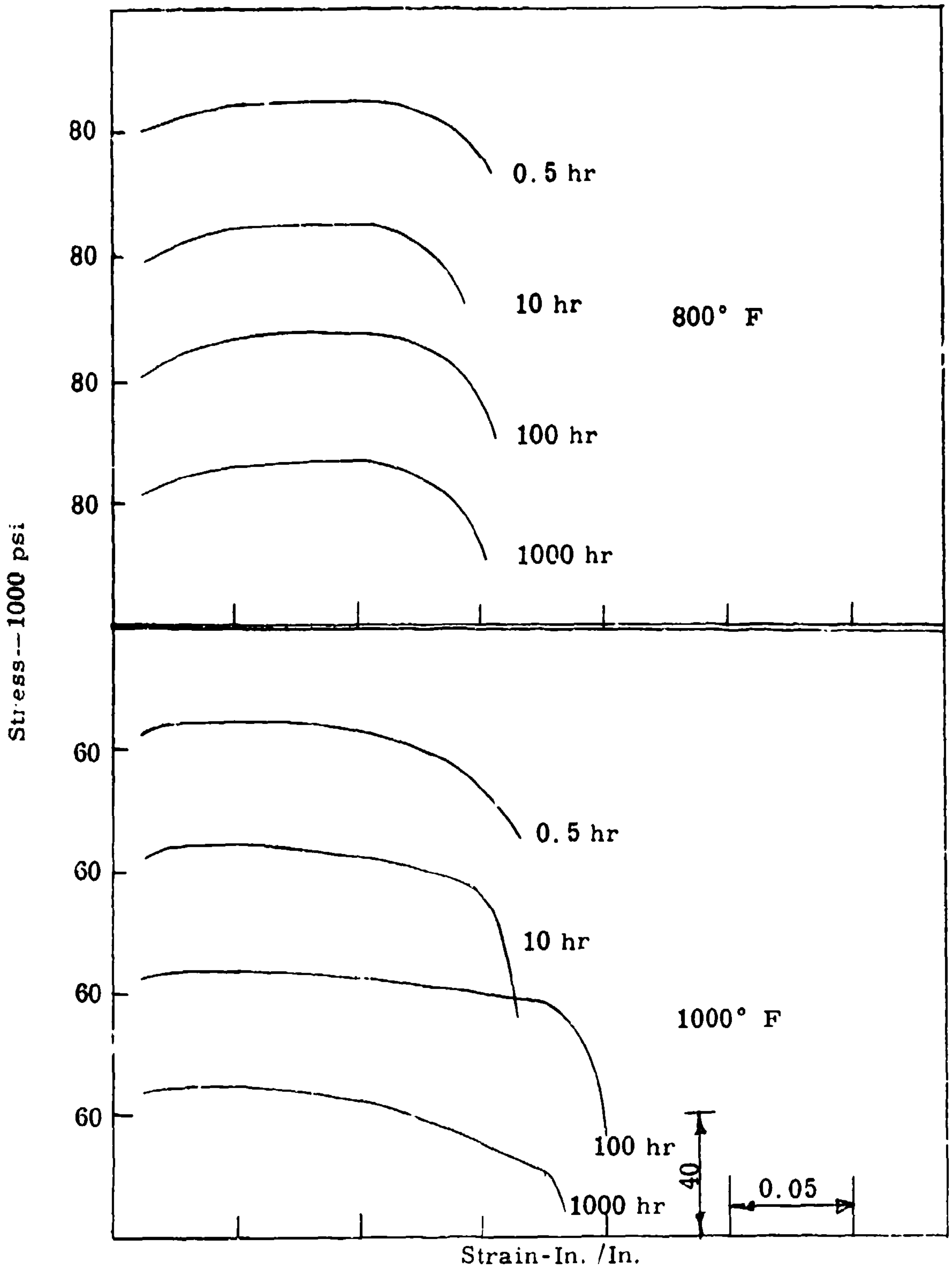


Fig. 129. Tensile postyield stress-strain curves for quenched and tempered 17-22 A (S) alloy steel sheet at various temperatures and exposure times.

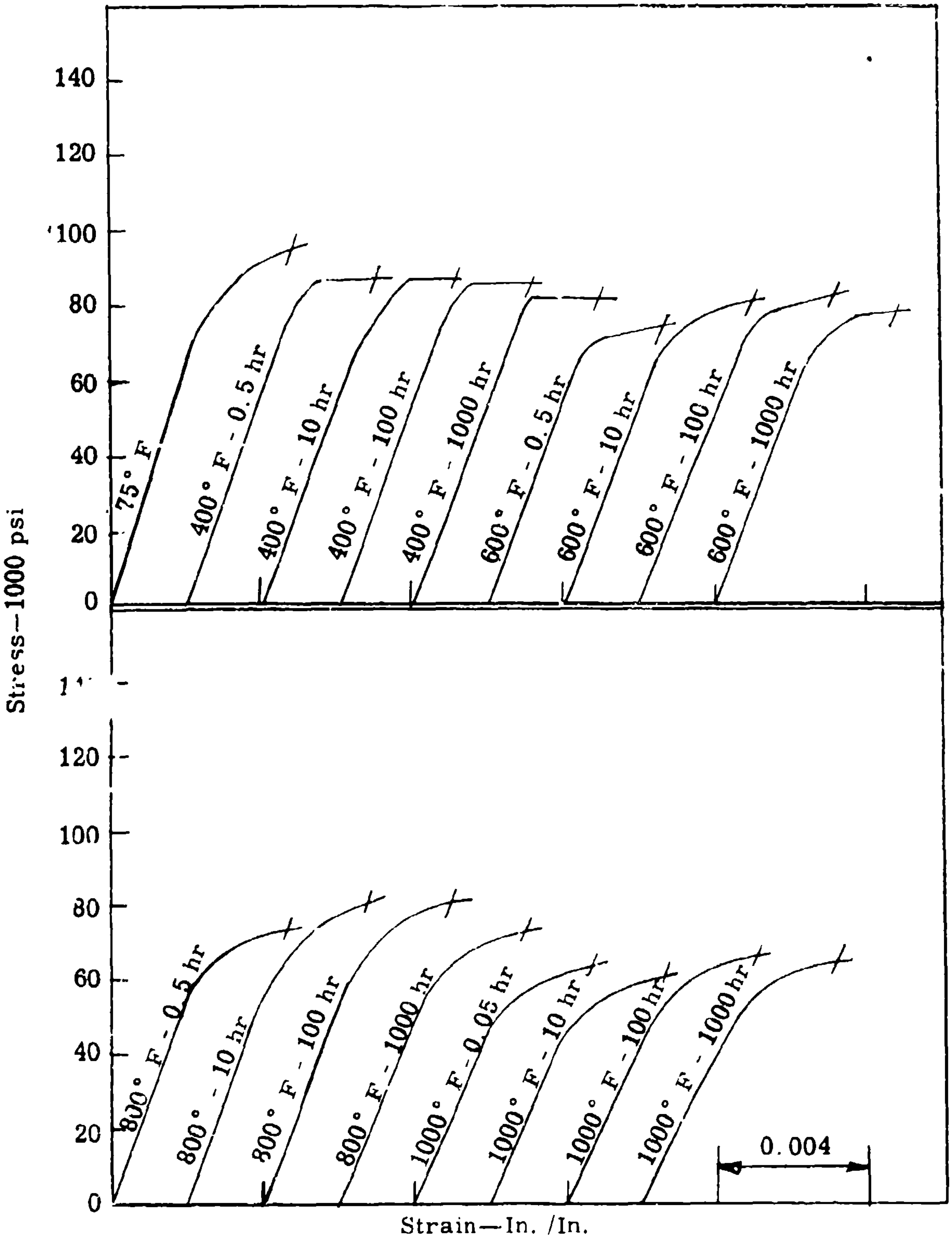


Fig. 130. Compressive stress-strain curves for quenched and tempered 17-22 A (S) alloy steel at various temperatures and exposure times.

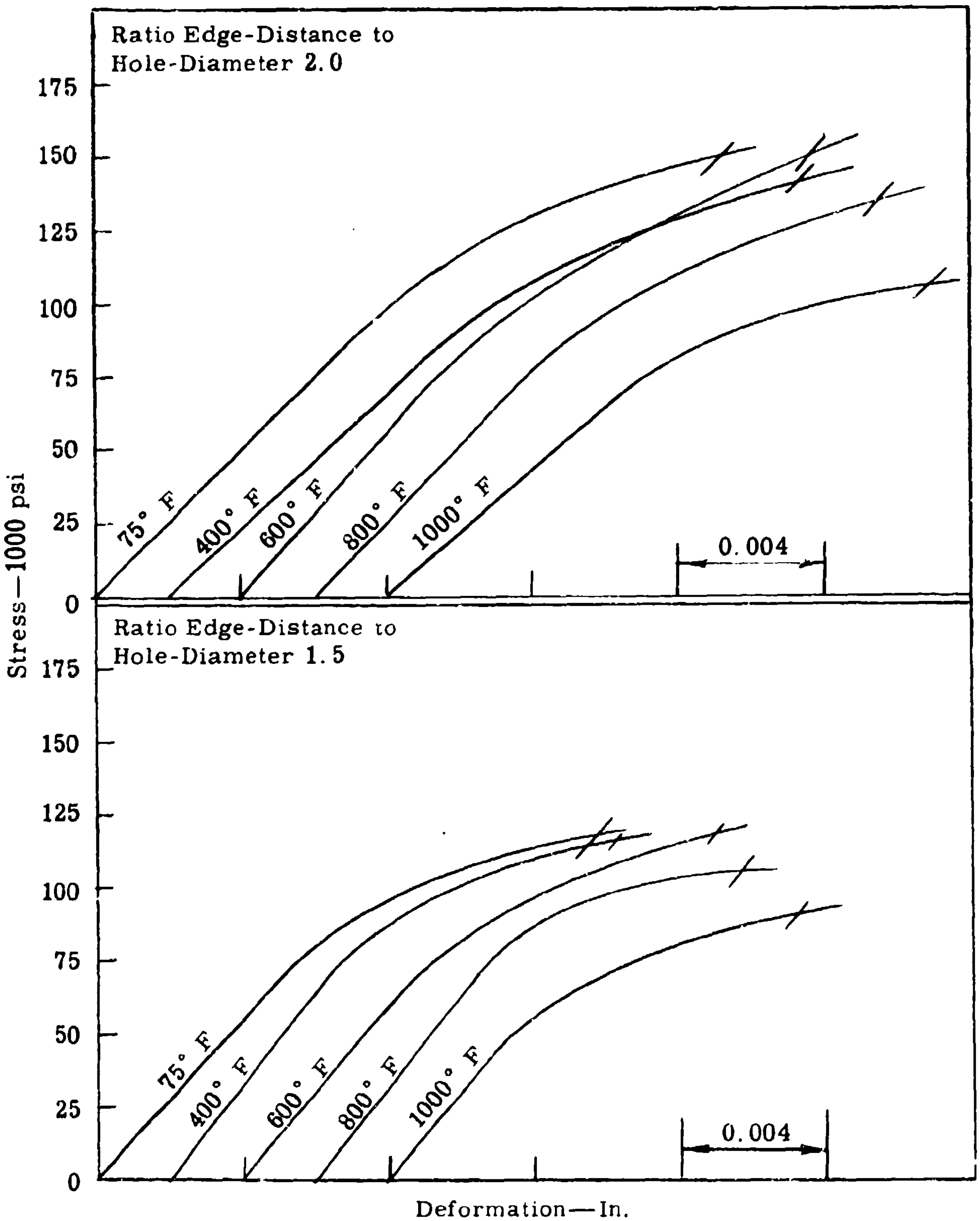


Fig. 131. Bearing stress-deformation curves for quenched and tempered 17-22 A (S) alloy steel sheet at various temperatures and one-half-hour exposure time.

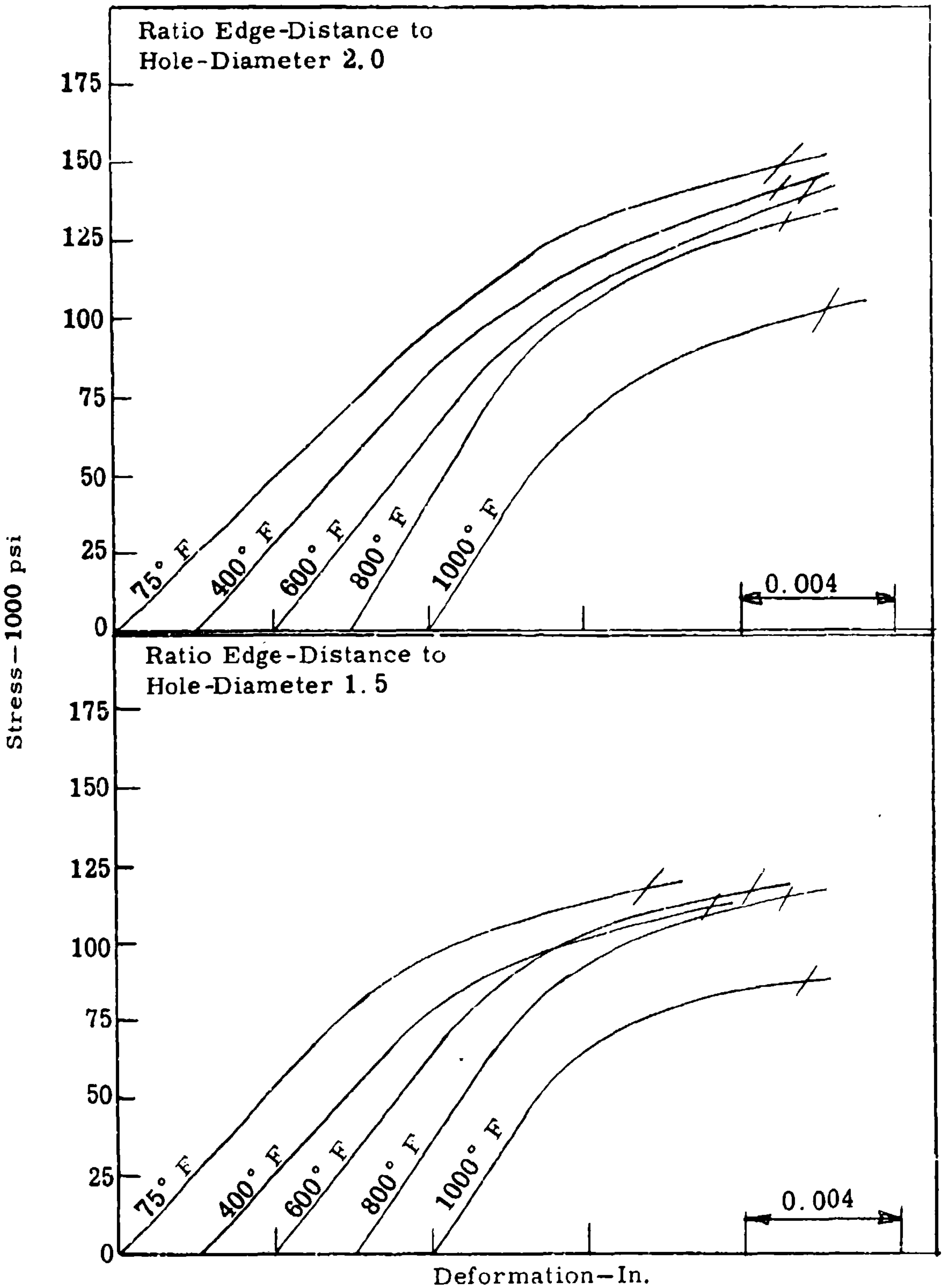


Fig. 132. Bearing stress-deformation curves for quenched and tempered 17-22 A (S) alloy steel sheet at various temperatures and ten-hour exposure time

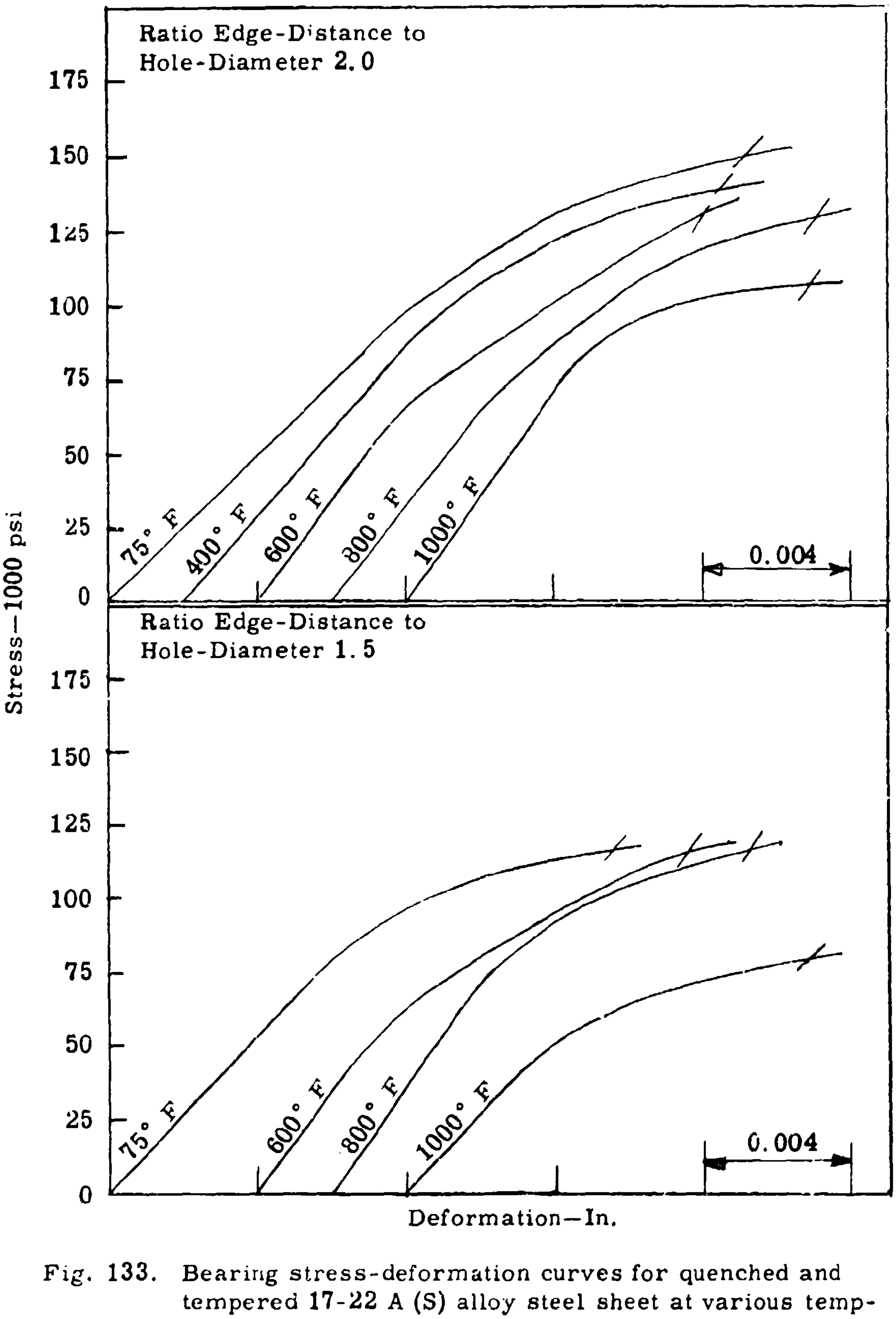


Fig. 133. Bearing stress-deformation curves for quenched and tempered 17-22 A (S) alloy steel sheet at various temperatures and one-hundred-hour exposure time

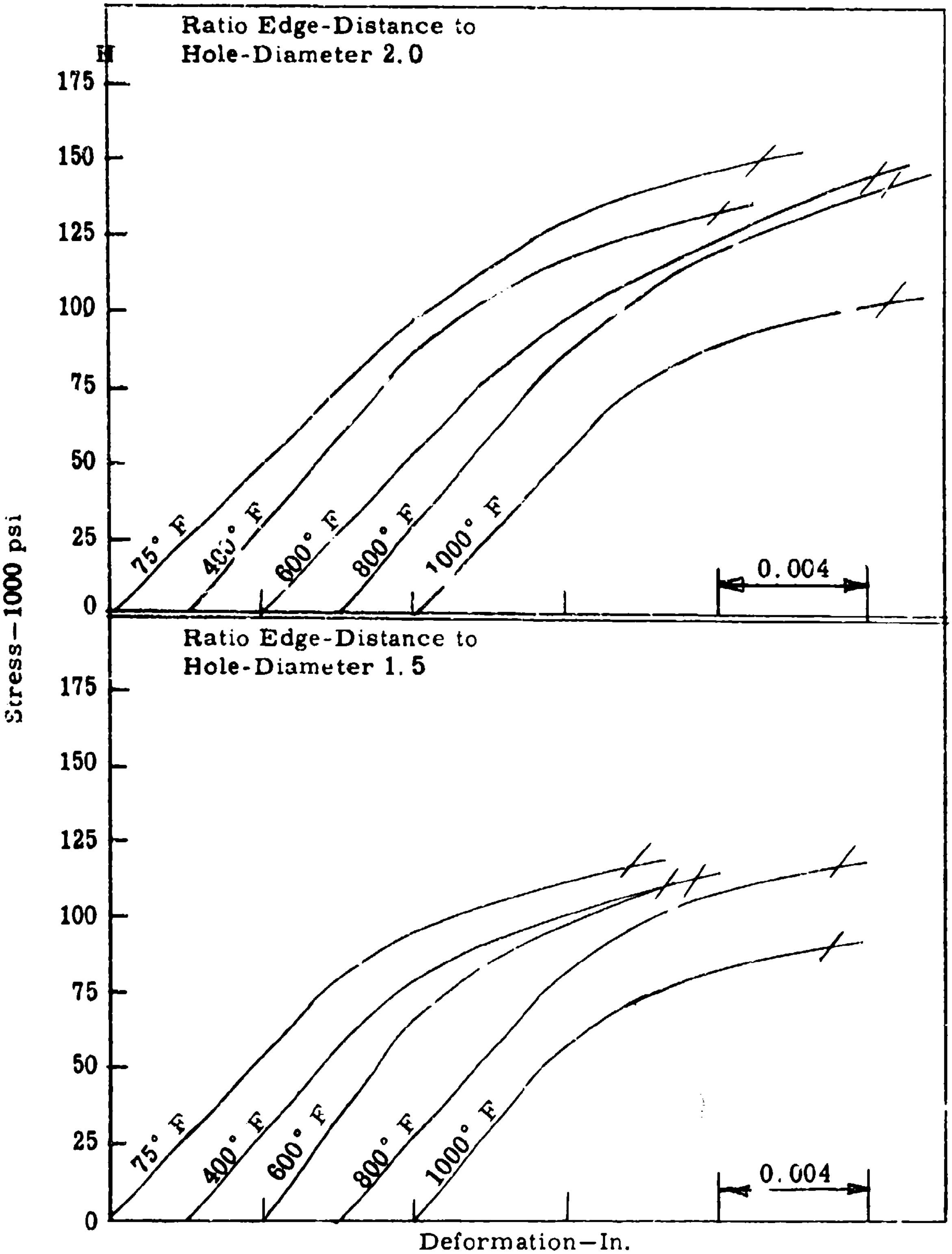


Fig. 134. Bearing stress-deformation curves for quenched and tempered 17-7 A (S) alloy steel sheet at various temperatures and one-thousand-hour exposure time.

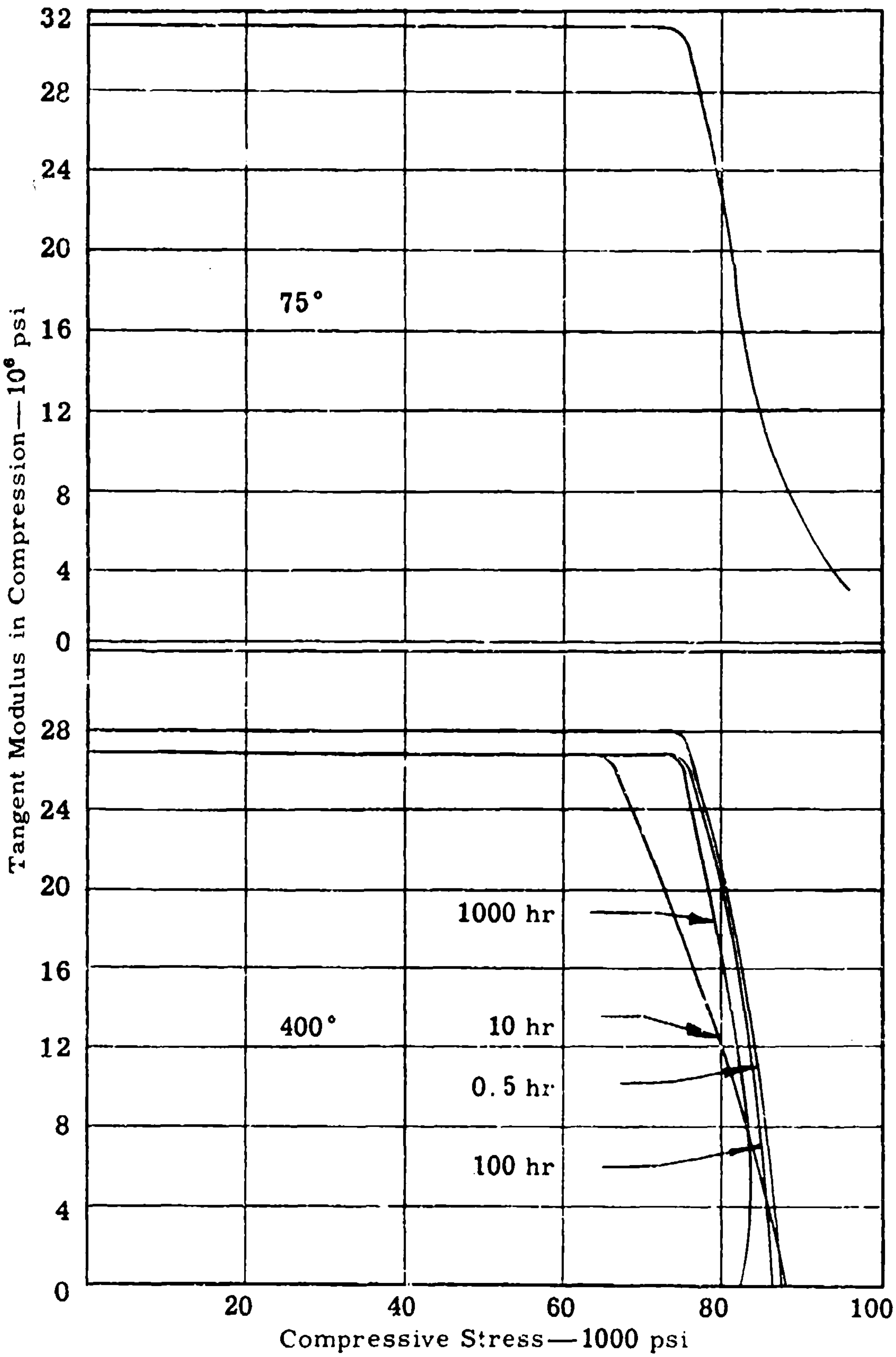


Fig. 135. Tangent-modulus vs. compressive-stress curves for quenched and tempered 17-22 A (S) alloy steel sheet at 75° F and 400° F and different exposure times.

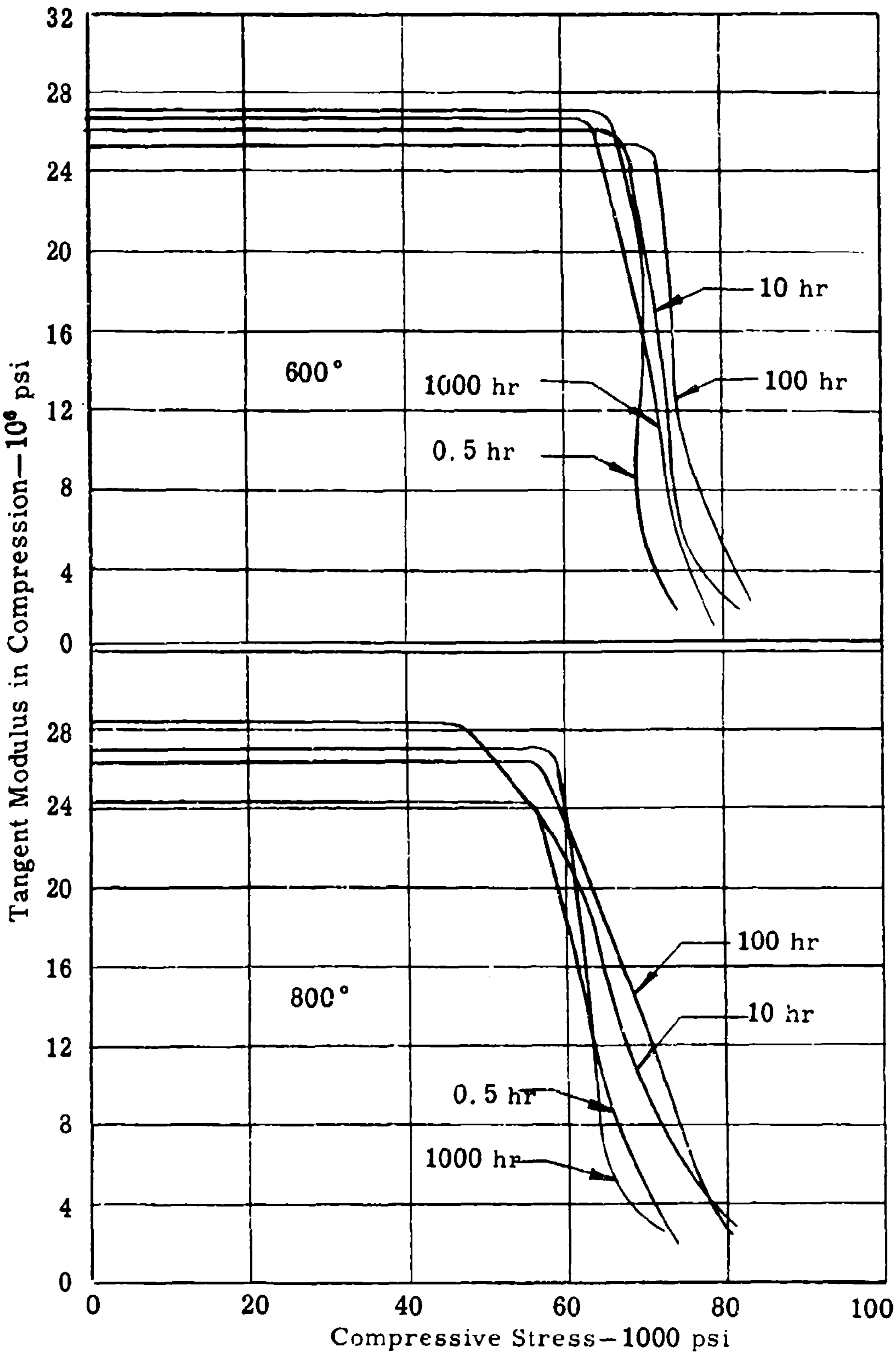


Fig. 136. Tangent-modulus vs. compressive-stress curves for quenched and tempered 17-22 A (S) alloy steel sheet at 600° F and 800° F and different exposure times.

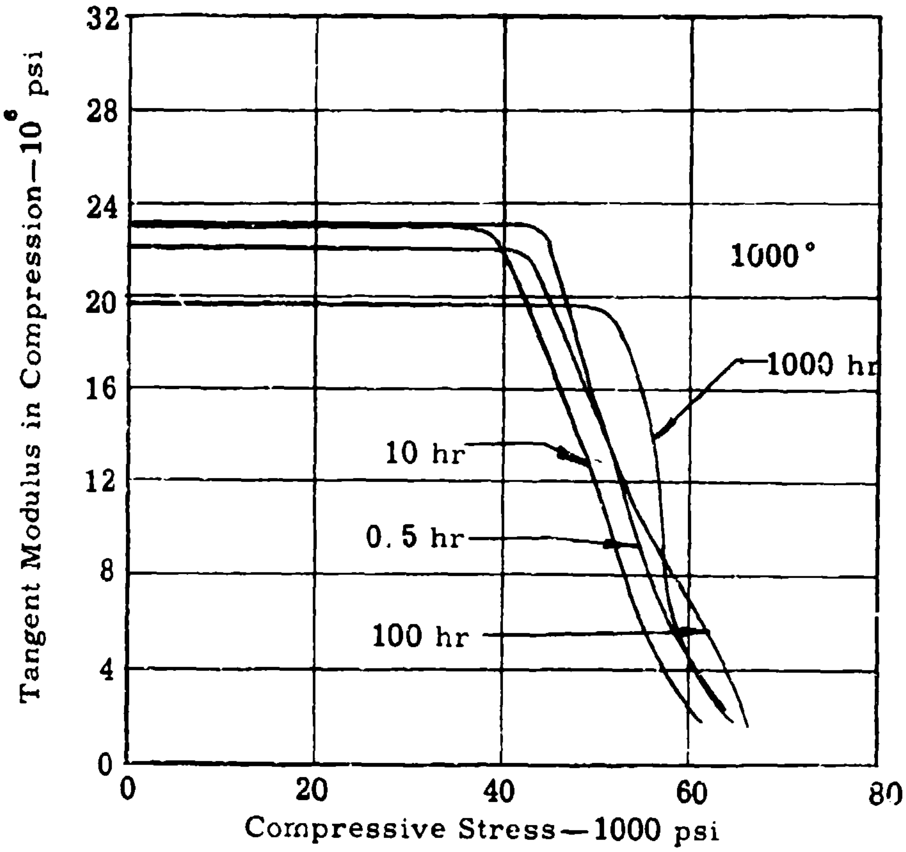


Fig. 137. Tangent-modulus vs. compressive-stress curves for quenched and tempered 17-22 A (s) alloy steel sheet at 1000° F and different exposure times.

Table 34

Tensile Properties of 0.062-In. 17-22A (S) Alloy Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| RT | | 101.6 | 110.5 | 31.7 | 15 | 23 | 87.6 | 197.5 |
| | | 100.5 | 112.0 | 29.1 | 16 | 22 | 77.0 | 216.0 |
| | | 97.5 | 109.0 | 29.7 | 16 | 22 | 75.7 | 169.5 |
| Avg | | 99.9 | 110.5 | 30.2 | 16 | 22 | 80.1 | 194.3 |
| 400 | 0.5 | 84.0 | 98.5 | 27.1 | 11 | 22 | 84.0 | 270.0 |
| | | 82.6 | 98.0 | 26.8 | 12 | 23 | 71.0 | 231.0 |
| | | 84.8 | 99.0 | 26.0 | 12 | 22 | 75.0 | 238.0 |
| Avg | | 83.8 | 98.5 | 26.6 | 12 | 22 | 75.5 | 246.3 |
| 400 | 10 | 82.4 | 98.5 | 25.3 | 12 | 22 | 78.0 | 176.0 |
| | | 85.8 | 100.0 | 26.2 | 10 | 22 | 78.5 | 256.0 |
| | | 80.6 | 95.7 | 26.0 | 12 | 21 | 74.0 | 237.0 |
| Avg | | 82.9 | 98.0 | 25.8 | 11 | 22 | 76.8 | 223.0 |
| 400 | 100 | 80.0 | 94.5 | 25.0 | 12 | 21 | 74.5 | 242.0 |
| | | 79.5 | 97.2 | 24.5 | 12 | 21 | 78.0 | 206.0 |
| | | 83.6 | 99.5 | 27.3 | 12 | 21 | 76.0 | 198.0 |
| Avg | | 81.0 | 97.0 | 25.6 | 12 | 21 | 76.1 | 215.3 |
| 400 | 1000 | 91.1 | 107.6 | 27.6 | 10 | 22 | 80.8 | 170.8 |
| | | 91.8 | 108.4 | 25.6 | 11 | 21 | 91.0 | 177.0 |
| | | 89.2 | 108.0 | 24.5 | 11 | 21 | 84.3 | 194.0 |
| Avg | | 90.7 | 108.0 | 25.9 | 11 | 21 | 85.3 | 180.6 |

Table 34 (continued)

Tensile Properties of 0.062-In. 17-22A (S) Alloy Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 600 | 0.5 | 85.5 | 102.9 | — | 13 | 22 | 74.4 | 172.8 |
| | | 79.8 | 100.0 | 27.7 | 14 | 23 | 71.0 | 158.9 |
| | | 86.5 | 103.0 | 26.4 | 13 | 25 | 77.6 | 192.5 |
| Avg | | 83.9 | 102.0 | 27.0 | 13 | 23 | 74.3 | 174.7 |
| 600 | 10 | 87.7 | 109.5 | 23.3 | 12 | 20 | 80.6 | 199.2 |
| | | 82.2 | 107.0 | 25.9 | 13 | 20 | 87.2 | 188.0 |
| | | 86.5 | 109.8 | 26.3 | 13 | 22 | 79.2 | 172.0 |
| Avg | | 85.5 | 108.8 | 25.2 | 13 | 21 | 82.3 | 186.4 |
| 600 | 100 | 86.2 | 109.5 | 27.5 | 12 | 22 | 82.8 | 165.2 |
| | | 86.2 | 106.5 | 26.4 | 12 | 23 | 75.0 | 194.0 |
| | | 87.8 | 108.2 | 26.1 | 12 | 23 | 78.2 | 176.2 |
| Avg | | 86.7 | 108.1 | 26.7 | 12 | 23 | 78.7 | 178.5 |
| 600 | 1000 | 86.0 | 110.8 | 22.7 | 11 | 20 | 95.8 | 181.5 |
| | | 85.8 | 108.8 | 28.1 | 12 | 20 | 78.7 | 193.0 |
| | | 85.8 | 107.8 | 28.2 | 11 | 19 | 77.5 | 145.5 |
| Avg | | 85.8 | 109.1 | 26.3 | 11 | 20 | 84.0 | 173.3 |
| 800 | 0.5 | 76.5 | 90.0 | 23.8 | 15 | 26 | 66.7 | 156.5 |
| | | 76.2 | 90.5 | 26.3 | 14 | 27 | 63.8 | 168.5 |
| | | 78.0 | 91.0 | 25.1 | 15 | 27 | 64.7 | 173.0 |
| Avg | | 76.9 | 90.5 | 25.1 | 15 | 27 | 65.1 | 166.0 |

Table 34 (continued)

Tensile Properties of 0.062-In. 17-22A (S) Alloy Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 800 | 10 | 74.8 | 89.2 | 22.8 | 12 | 22 | 71.8 | 165.4 |
| | | 73.7 | 87.8 | 23.9 | 11 | 22 | 58.7 | 145.6 |
| | | 74.6 | 89.7 | 25.5 | 11 | 22 | 65.2 | 165.8 |
| Avg | | 74.4 | 88.9 | 24.1 | 11 | 22 | 65.2 | 158.9 |
| 800 | 100 | 77.4 | 93.7 | 27.0 | 13 | 21 | 71.5 | 200.0 |
| | | 79.4 | 95.4 | 26.7 | 13 | 23 | 61.2 | 159.5 |
| | | 78.2 | 93.7 | 25.9 | 12 | 22 | 57.5 | 145.0 |
| Avg | | 78.3 | 94.3 | 26.5 | 13 | 22 | 63.4 | 168.2 |
| 800 | 1000 | 78.8 | 95.4 | 19.4 | 11 | 21 | 70.8 | 154.0 |
| | | 77.8 | 93.2 | 25.0 | 14 | 22 | 61.0 | 132.0 |
| | | 83.5 | 98.8 | 28.6 | 13 | 22 | 74.0 | 159.5 |
| Avg | | 80.0 | 95.8 | 24.2 | 13 | 22 | 68.6 | 148.5 |
| 1000 | 0.5 | 71.0 | 72.6 | 21.3 | 18 | 22 | 16.0 | 75.0 |
| | | 61.0 | 69.0 | 20.3 | 16 | 20 | 31.9 | 107.5 |
| | | 53.6 | 69.6 | 20.7 | 16 | 21 | 34.5 | 122.2 |
| Avg | | 63.5 | 70.4 | 20.9 | 17 | 21 | 27.4 | 101.5 |
| 1000 | 10 | 60.3 | 67.7 | 25.2 | 15 | 26 | 11.8 | 33.8 |
| | | 62.0 | 68.5 | 24.7 | 20 | 25 | 25.8 | 75.0 |
| | | 66.1 | 69.1 | — | 13 | 26 | 11.8 | 33.3 |
| Avg | | 62.8 | 68.4 | 25.0 | 16 | 26 | 16.5 | 47.0 |

Table 34 (continued)

Tensile Properties of 0.062-In. 17-22A (S) Alloy Steel[4] Sheet at Different Temperatures and Holding Times

| Temp °F | Holding Time, hr | YS 1000 psi | UTS 1000 psi | ME $10^6$ psi | Elong. % | Hard[1] R45N | RS[2] 1000 psi | RS[3] 1000 psi |
|---|---|---|---|---|---|---|---|---|
| 1000 | 100 | 62.8 | 68.4 | 28.3 | 14 | 24 | 15.3 | 55.4 |
| | | 64.4 | 67.0 | 22.5 | 18 | 22 | 13.6 | 50.0 |
| | | 63.2 | 67.7 | 24.3 | 22 | 21 | 12.3 | 59.2 |
| Avg | | 63.5 | 67.7 | 25.0 | 18 | 22 | 13.7 | 54.9 |
| 1000 | 1000 | 63.8 | 68.7 | 21.6 | 15 | 24 | 28.6 | 120.0 |
| | | 64.7 | 68.8 | 21.7 | 17 | 23 | — | — |
| | | 68.2 | 71.0 | 21.6 | 19 | 22 | 10.6 | 35.3 |
| Avg | | 65.6 | 69.5 | 21.6 | 17 | 23 | 19.6 | 77.6 |

1. Hardness determinations made at room temperature after tests.
2. Rupture strength based on original cross section.
3. Rupture strength based on final cross section.
4. Heat treatment — 1750° F 15 min argon atmosphere, O. Q., 1300° F 1 hr, A. C.

Table 35

Tensile Strength of 3/16-In. 17-22 A (S) Alloy Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC |
| RT | | | | | | | 116.5 | 22 |
| | | | | | | | 114.0 | 22 |
| | | | | | | | 120.0 | 23 |
| Avg | | | | | | | 116.8 | 22 |
| 400 | 106.5 | 22 | 111.2 | 23 | 110.2 | 26 | 114.0 | 23 |
| | 109.0 | 21 | 110.5 | 22 | 113.0 | 26 | 114.8 | 23 |
| | 111.0 | 24 | 114.5 | 23 | 117.0 | 26 | 114.0 | 23 |
| Avg | 108.8 | 22 | 112.0 | 23 | 113.4 | 26 | 114.3 | 23 |
| 600 | 115.0 | 26 | 112.5 | 26 | 117.0 | 26 | 108.8 | 23 |
| | 113.0 | 26 | 112.3 | 26 | 117.7 | 26 | 117.2 | 27 |
| | 113.0 | 26 | 116.2 | 25 | 117.0 | 27 | 109.2 | 23 |
| Avg | 113.7 | 26 | 113.7 | 26 | 117.2 | 26 | 111.7 | 24 |
| 800 | 94.5 | 23 | 99.9 | 24 | 97.4 | 24 | 96.0 | 22 |
| | 95.2 | 21 | 100.5 | 24 | 96.2 | 25 | 100.4 | 22 |
| | 95.5 | 23 | 97.0 | 23 | 96.5 | 23 | 102.0 | - |
| Avg | 95.1 | 22 | 99.1 | 24 | 96.7 | 24 | 99.5 | 22 |

Table 35(continued)

Tensile Strength of 3/16-In. 17-22 A (S) Alloy Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp ° F | UTS[1] 1000 psi | Hard[2] RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC | UTS 1000 psi | Hard RC |
| 1000 | 74.0 | 24 | 82.0 | 28 | 74.2 | 23 | 71.3 | 24 |
| | 75.5 | 24 | 80.5 | 26 | 74.7 | 24 | 70.5 | 26 |
| | 74.7 | 24 | 77.2 | 28 | 74.7 | 24 | 72.2 | 23 |
| | 74.7 | 24 | 79.9 | 27 | 74.5 | 24 | 71.3 | 24 |

1. Ultimate tensile strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment – 1750° F 15 min argon atmosphere, O. Q., 1300° F, 1 hr, A. C.

Table 36

Compressive Properties of 0.062-In. 17-22 A (S) Alloy Steel[3] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | CYS[1] 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| RT | | | | | | | | | | 95.5 | 31.0 | 21 |
| | | | | | | | | | | 96.0 | 32.6 | 21 |
| | | | | | | | | | | 94.5 | 30.2 | 21 |
| Avg | | | | | | | | | | 95.3 | 31.3 | 21 |
| 400 | 90.5 | 27.8 | 20 | 89.5 | 29.4 | 18 | 86.3 | 26.1 | 18 | 87.5 | 27.8 | 18 |
| | 87.5 | 27.9 | 18 | 81.5 | 26.7 | 19 | 86.3 | 23.6 | 19 | 82.5 | 26.8 | 18 |
| | 87.0 | 27.9 | 20 | 97.0 | 25.5 | 19 | 83.5 | 29.9 | 21 | 83.0 | 28.0 | 18 |
| Avg | 88.3 | 27.9 | 19 | 89.3 | 27.2 | 19 | 85.4 | 27.5 | 19 | 84.3 | 27.5 | 18 |
| 600 | 77.6 | 23.8 | 17 | 78.[illegible] | 25.7 | 18 | 78.8 | 29.2 | 17 | 84.8 | 28.8 | 19 |
| | 76.5 | 26.4 | 17 | 81.8 | 26.0 | 18 | 79.0 | 28.8 | 17 | 79.2 | 26.6 | 18 |
| | 74.8 | 27.0 | 18 | [illegible]1.7 | — | 19 | 83.5 | 25.3 | 18 | 79.0 | 23.1 | 20 |
| Avg | 76.3 | 25.7 | 17 | 80.6 | 25.8 | 18 | 80.4 | 27.7 | 17 | 81.0 | 26.2 | 19 |
| 800 | 73.7 | 26.9 | 19 | 76.7 | 27.7 | 21 | 80.6 | 26.3 | 21 | 71.7 | 26.4 | 19 |
| | 72.0 | 22.1 | 19 | 81.0 | 28.5 | 21 | 72.5 | 28.7 | 21 | 68.7 | 23.7 | 20 |
| | 78.0 | 24.0 | 21 | 84.7 | 28.2 | 23 | 73.6 | 24.6 | 20 | 72.8 | 24.2 | 21 |
| Avg | 74.6 | 24.3 | 20 | 80.8 | 28.1 | 22 | 75.6 | 26.5 | 21 | 71.1 | 24.8 | 20 |

Table 36 (continued)

Compressive Properties of 0.062-In. 17-22 A (S) Alloy Steel[3] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | CYS[1] 1000 psi | ME $10^6$ psi | Hard[2] R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N | CYS 1000 psi | ME $10^6$ psi | Hard R45N |
| 1000 | 73.0 | 21.7 | 23 | 60.8 | - | 19 | 61.3 | 22.2 | 19 | 65.0 | 19.7 | 20 |
| | 64.0 | 23.1 | 21 | 65.2 | 20.9 | 19 | 72.7 | 22.3 | 21 | 65.5 | - | 21 |
| | 65.3 | 25.3 | 21 | 64.3 | 23.0 | 19 | 66.2 | 22.1 | 20 | 66.5 | 18.7 | 21 |
| Avg | 67.4 | 23.4 | 22 | 63.4 | 22.0 | 19 | 66.7 | 22.2 | 20 | 65.7 | 19.2 | 21 |

1. Compressive yield strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment – 1750° F 15 min argon atmosphere, O. Q., 1300° F 1 hr, A. C.

Table 37

**Shear Strength of 3/16-In. 17-22A (S) Alloy Steel[3] Plate at Different Temperatures and Holding Times**

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | USS[1] 1000 psi | Hard[2] RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC |
| RT | | | | | | | 75.7 | 23 |
| | | | | | | | 74.8 | 22 |
| | | | | | | | 73.5 | 23 |
| Avg | | | | | | | 74.7 | 23 |
| 400 | 67.8 | 21 | 62.5 | 17 | 69.2 | 22 | 68.0 | 19 |
| | 69.8 | 21 | 63.0 | 19 | 69.8 | 19 | 67.3 | 18 |
| | 69.2 | 21 | 62.5 | 18 | 67.2 | 22 | 66.2 | 19 |
| Avg | 68.9 | 21 | 62.6 | 18 | 68.7 | 21 | 67.1 | 19 |
| 600 | 72.5 | 20 | 71.8 | 22 | 68.2 | 22 | 73.6 | 22 |
| | 71.5 | 21 | 71.5 | 23 | 70.2 | 22 | 73.2 | 17 |
| | 73.1 | 18 | 71.5 | 23 | 71.5 | 23 | 72.0 | 18 |
| Avg | 72.4 | 20 | 71.6 | 23 | 70.0 | 22 | 72.9 | 19 |
| 800 | 74.0 | 19 | 62.5 | 16 | 63.5 | 19 | 61.2 | 20 |
| | 65.6 | 21 | 63.0 | 16 | 60.4 | 17 | 61.2 | 20 |
| | 65.5 | 23 | 62.0 | – | 58.2 | 19 | 60.2 | 20 |
| Avg | 68.4 | 21 | 62.5 | 16 | 60.7 | 18 | 60.9 | 20 |

Table 37 (continued)

Shear Strength of 3/16-In. 17-22A (S) Alloy Steel[3] Plate at Different Temperatures and Holding Times

| Holding Time, hr | 1/2 | | 10 | | 100 | | 1000 | |
|---|---|---|---|---|---|---|---|---|
| Temp °F | USS[1] 1000 psi | Hard[2] RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC | USS 1000 psi | Hard RC |
| 1000 | 50.0 | 14 | 50.5 | 14 | 46.2 | 15 | 45.4 | 18 |
| | 56.5 | 20 | 49.7 | 15 | 46.7 | 15 | 44.4 | 17 |
| | 53.0 | 14 | 52.5 | 14 | 45.0 | 14 | 46.2 | 17 |
| Avg | 53.2 | 16 | 50.9 | 14 | 46.0 | 15 | 45.3 | 17 |

1. Ultimate shear strength.
2. Hardness determinations made at room temperature after tests.
3. Heat treatment — 1750° F 15 min argon atmosphere, O. Q., 1300° F 1 hr, A. C.

## Table 38

**Bearing Properties[4] of 0.062-In. 17-22 A (S) Alloy Steel[5] Sheet at Different Temperatures and Holding Times**

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp °F | BYS[1] 1000 psi | UBS[2] 1000 psi | Hard[3] R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N | BYS 1000 psi | UBS 1000 psi | Hard R45N |
| RT | | | | | | | | | | 114.5 | 155.0 | 23 |
| | | | | | | | | | | 120.0 | 162.0 | 24 |
| | | | | | | | | | | 118.0 | 160.5 | 23 |
| Avg | | | | | | | | | | 117.5 | 159.2 | 23 |
| 400 | 117.5 | 153.0 | 22 | 101.5 | 157.5 | 22 | | | | 106.5 | 157.0 | 21 |
| | 107.5 | 147.0 | 23 | 112.0 | 156.7 | 21 | | | | 122.0 | 156.0 | 22 |
| | 117.5 | 153.0 | 22 | 113.5 | 157.5 | 22 | | | | 111.0 | 164.0 | 22 |
| Avg | 114.2 | 151.0 | 22 | 108.7 | 157.2 | 22 | | | | 113.2 | 159.0 | 22 |
| 600 | 122.0 | 147.5 | 22 | 116.0 | 168.0 | 21 | 114.0 | 163.2 | 19 | 119.2 | 164.5 | 21 |
| | 118.0 | 156.0 | 24 | 118.5 | 159.4 | 21 | 117.0 | 170.5 | 20 | 113.0 | 166.5 | 19 |
| | 113.0 | 148.5 | 23 | 115.5 | 162.5 | 17 | 119.0 | 164.5 | 22 | 113.8 | 163.5 | 20 |
| Avg | 117.7 | 150.7 | 23 | 116.7 | 163.3 | 20 | 116.7 | 166.1 | 20 | 115.3 | 164.8 | 20 |
| 800 | 106.0 | 135.0 | 22 | 122.5 | 144.0 | 19 | 117.2 | 145.0 | 19 | 118.5 | 142.2 | 19 |
| | 113.0 | 135.0 | 24 | 121.8 | 142.5 | 21 | 117.5 | 146.2 | 18 | 115.5 | 144.5 | 20 |
| | 97.0 | 135.0 | 23 | 118.2 | 146.0 | 19 | 121.2 | 146.5 | 20 | 117.8 | 143.5 | 22 |
| Avg | 105.3 | 135.0 | 23 | 117.5 | 144.2 | 20 | 118.6 | 145.9 | 19 | 117.3 | 143.7 | 20 |

Table 38 (continued)

Bearing Properties[4] of 0.062-In. 17-22 A (S) Alloy Steel[5] Sheet at Different Temperatures and Holding Times

| Hold Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp ° F | BYS[1] | UBS[2] | Hard[3] | BYS | UBS | Hard | BYS | UBS | Hard | BYS | UBS | Hard |
| | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N |
| 1000 | 91.8 | 114.8 | 22 | 84.2 | 104.0 | 22 | – | 106.0 | 21 | 85.3 | 100.0 | 21 |
| | 99.0 | 109.0 | 21 | 84.8 | 103.0 | 21 | 71.2 | 103.8 | 21 | 91.0 | 101.5 | 19 |
| | – | 107.5 | 22 | 88.7 | 106.5 | 22 | 86.5 | 106.0 | 21 | 89.5 | 101.5 | 20 |
| Avg | 95.4 | 111.1 | 22 | 85.9 | 104.5 | 22 | 78.8 | 105.3 | 21 | 88.6 | 101.0 | 20 |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at room temperature after tests.
4. Edge – Distance to hold-diameter ratio 1.5 in.
5. Heat treatment – 1750° F 15 min argon atmosphere, O.Q., 1300° F 1 hr, A. C.

Table 39

Bearing Properties[4] of 0.062-In. 17-22 A (S) Alloy Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr / Temp °F | 1/2 BYS[1] (1000 psi) | 1/2 UBS[2] (1000 psi) | 1/2 Hard[3] R45N | 10 BYS (1000 psi) | 10 UBS (1000 psi) | 10 Hard R45N | 100 BYS (1000 psi) | 100 UBS (1000 psi) | 100 Hard R45N | 1000 BYS (1000 psi) | 1000 UBS (1000 psi) | 1000 Hard R45N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RT | | | | | | | | | | 174.5 | 221.0 | 23 |
| | | | | | | | | | | 150.0 | 213.0 | 22 |
| | | | | | | | | | | 145.5 | 213.0 | 23 |
| Avg | | | | | | | | | | 156.7 | 215.7 | 23 |
| 400 | 143.0 | 209.0 | 24 | 142.0 | 206.0 | 22 | 125.0 | 211.0 | 21 | 144.0 | 212.0 | 22 |
| | 142.5 | 206.0 | 24 | 130.0 | 194.5 | 22 | 149.0 | 211.5 | 21 | 133.0 | 215.0 | 21 |
| | 140.0 | 205.0 | 23 | 139.5 | 206.0 | 22 | 141.0 | 196.0 | 22 | 132.5 | 215.0 | 22 |
| Avg | 141.8 | 206.7 | 24 | 137.2 | 202.2 | 22 | 138.3 | 206.2 | 21 | 136.5 | 214.0 | 22 |
| 600 | 150.0 | 212.0 | 23 | 139.2 | 207.0 | 23 | 131.2 | 212.0 | 21 | 134.0 | 221.0 | 20 |
| | 144.0 | 208.5 | 24 | 143.2 | 215.0 | 21 | 126.5 | 213.0 | 21 | 145.2 | 215.5 | 20 |
| | 145.5 | 208.5 | 23 | – | 215.0 | 22 | 144.2 | 211.0 | 22 | 148.5 | 215.0 | 21 |
| Avg | 146.5 | 209.7 | 23 | 141.2 | 213.2 | 22 | 134.0 | 212.0 | 21 | 142.6 | 217.2 | 20 |
| 800 | 135.5 | 182.5 | 22 | 138.5 | 187.5 | 20 | 133.0 | 183.5 | 20 | 124.5 | 192.0 | 22 |
| | 134.0 | 180.0 | 22 | 135.2 | 178.0 | 22 | 161.5 | 187.5 | 21 | 144.2 | 189.8 | 24 |
| | 134.0 | 183.5 | 22 | 132.3 | 183.0 | 20 | 129.5 | 186.6 | 21 | 149.2 | 194.0 | 22 |
| Avg | 134.5 | 182.0 | 22 | 135.0 | 182.8 | 21 | 141.3 | 185.9 | 21 | 139.6 | 191.9 | 23 |

Table 39 (continued)

Bearing Properties[4] of 0.062-In. 17-22 A (S) Alloy Steel[5] Sheet at Different Temperatures and Holding Times

| Hold. Time hr | 1/2 | | | 10 | | | 100 | | | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temp ° F | BYS[1] | UBS[2] | Hard[3] | BYS | UBS | Hard | BYS | UBS | Hard | BYS | UBS | Hard |
| | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N | 1000 psi | | R45N |
| 1000 | 117.8 | 150.0 | 21 | 100.8 | 139.5 | 25 | 112.9 | 133.9 | 21 | 93.0 | 132.5 | 21 |
| | 110.0 | 143.2 | 22 | 103.0 | 140.0 | 23 | - | 136.5 | 23 | - | 125.0 | 23 |
| | 106.0 | 145.5 | 21 | 105.5 | 138.2 | 23 | 107.5 | 136.5 | 22 | 103.0 | 129.5 | 20 |
| Avg | 111.3 | 146.2 | 21 | 103.1 | 139.2 | 24 | 110.2 | 135.6 | 22 | 98.0 | 129.0 | 21 |

1. Bearing yield strength.
2. Ultimate bearing strength.
3. Hardness determinations made at roomtemperature after tests.
4. Edge-distance to hole-diameter ratio 2.0.
5. Heat treatment - 1750° F 15 min argon atmosphere, O.Q., 1300° F 1 hr, A. C.

## 10.7 Comparative Figures and Tables

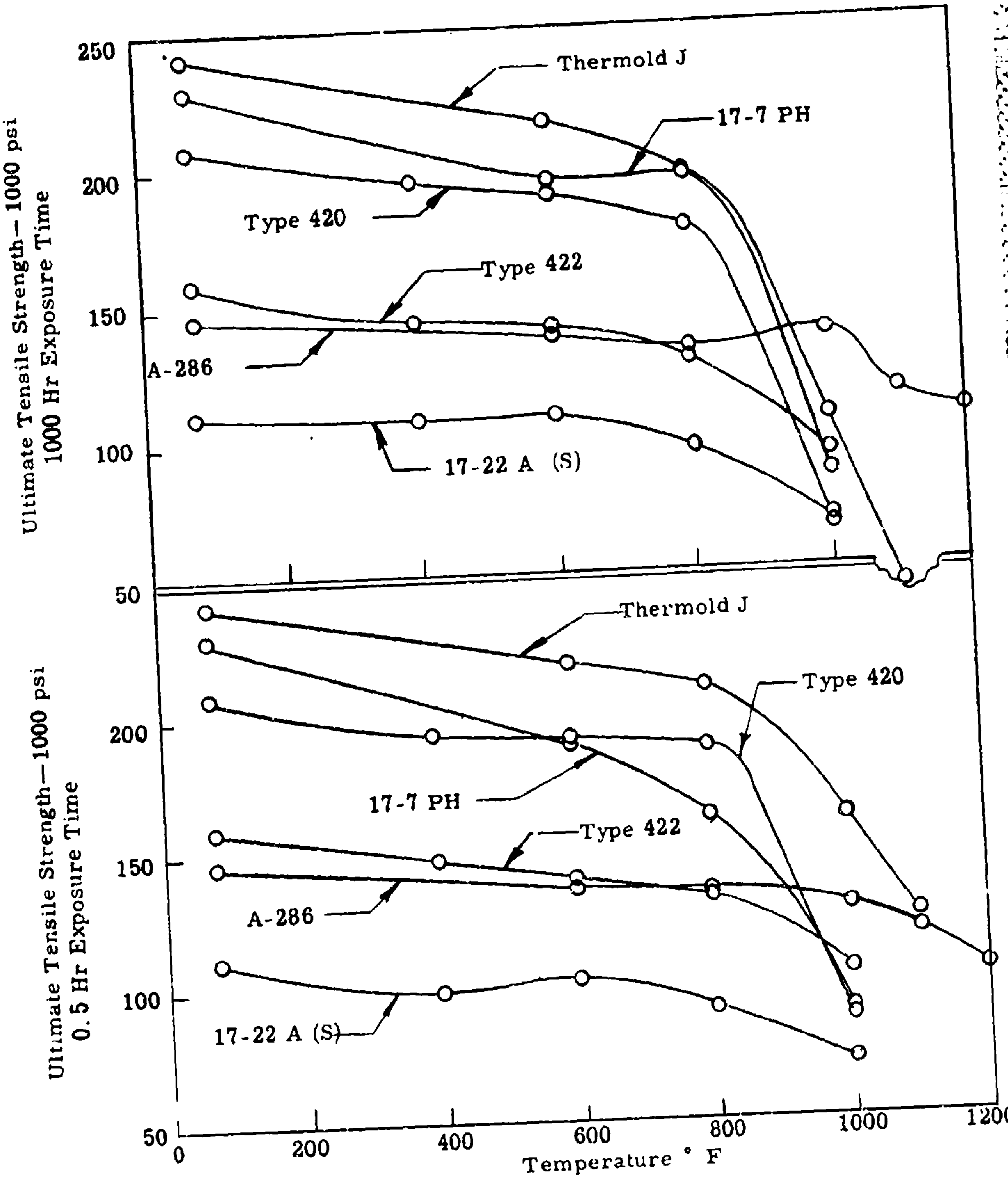


Fig. 138. Effect of temperature on the ultimate tensile strength of the test materials after exposures of 1000 hours and of 0.5 hour.

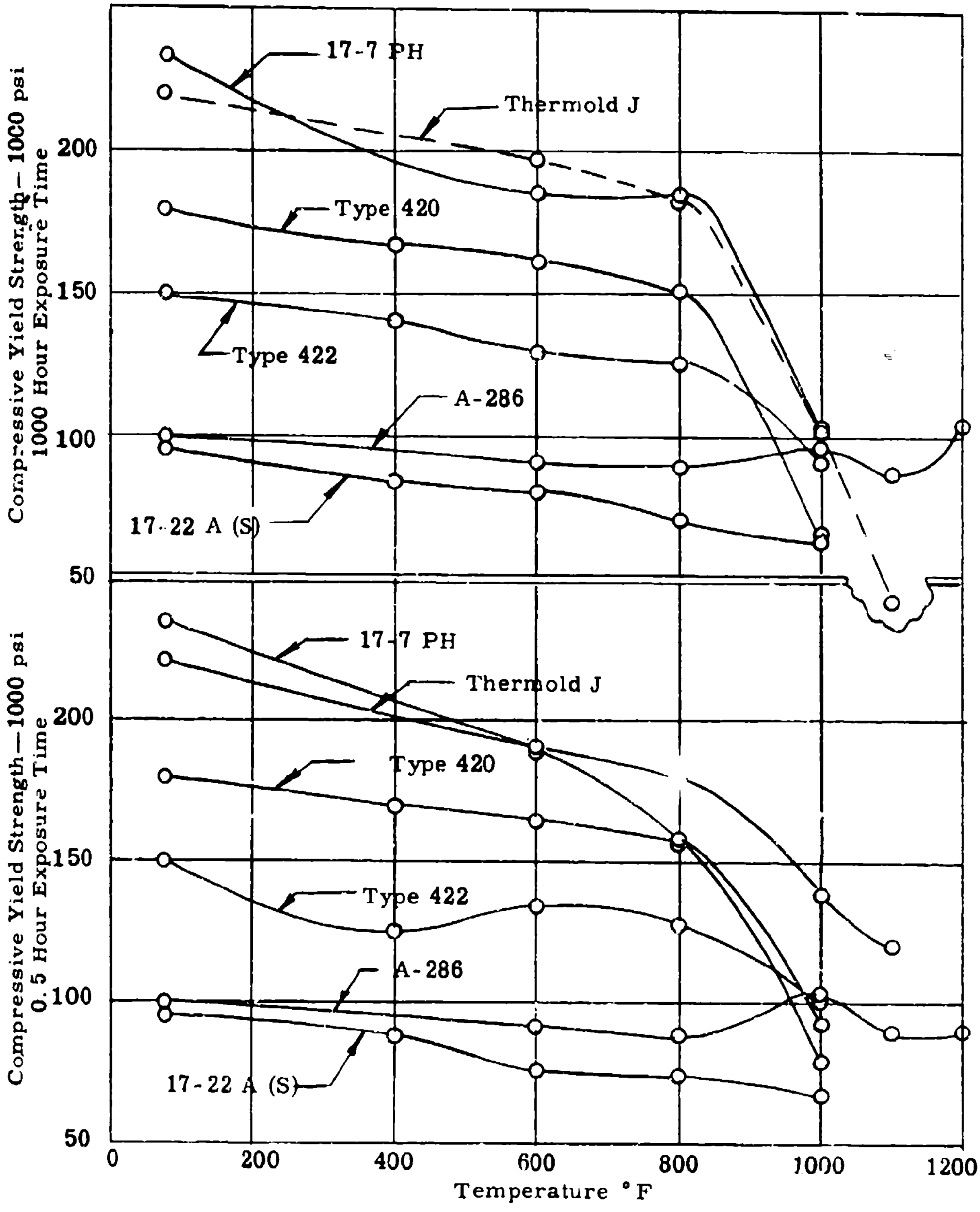


Fig. 139. Effect of temperature on the compressive yield strength of the test materials after exposures of 1000 hours and of 0.5 hour.

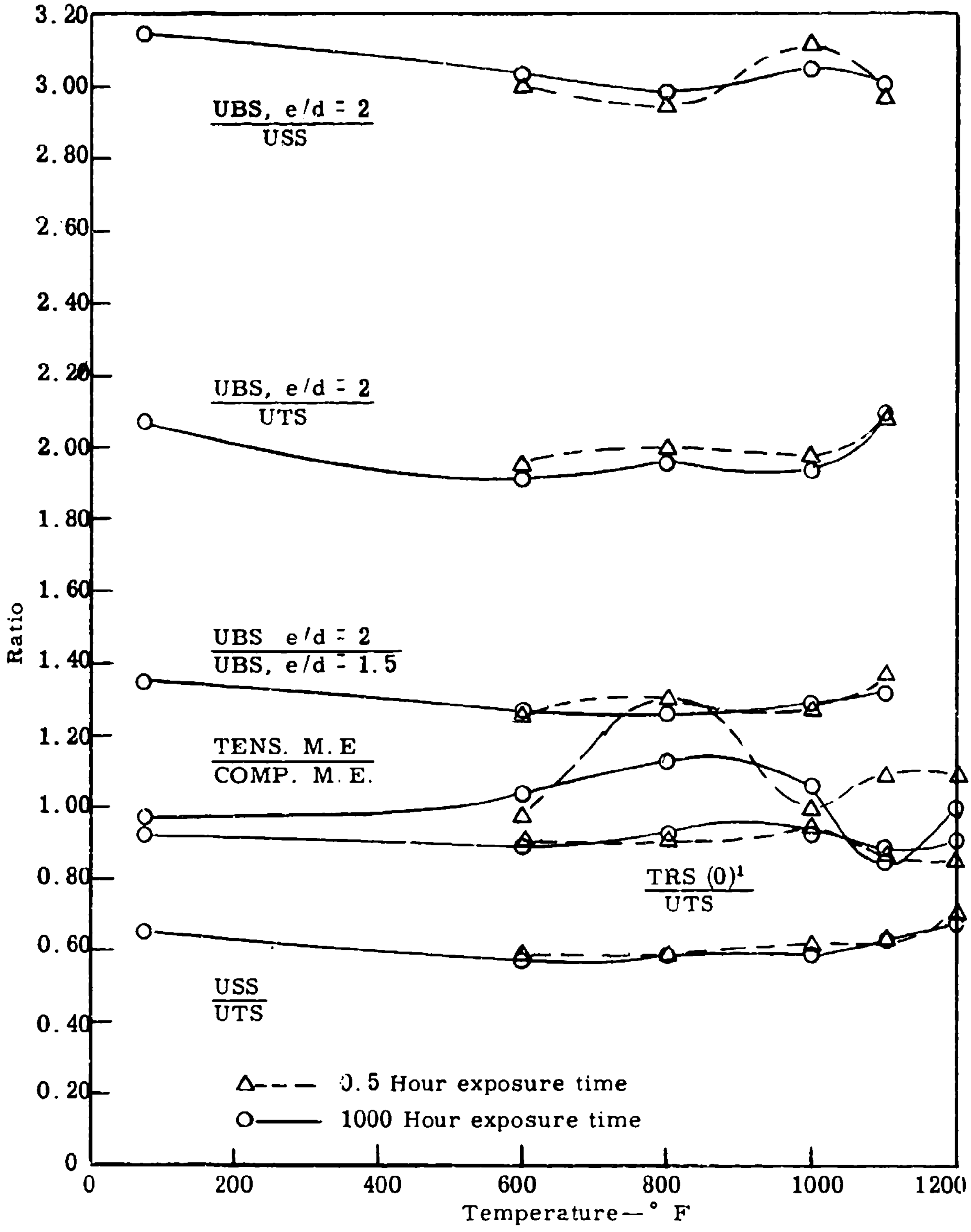


Fig. 140. Effect of temperature on six ratio relationships of properties of quenched and tempered A-286 austenitic alloy sheet.

1. TRS (0)—Tensile rupture stength based on the original cross section

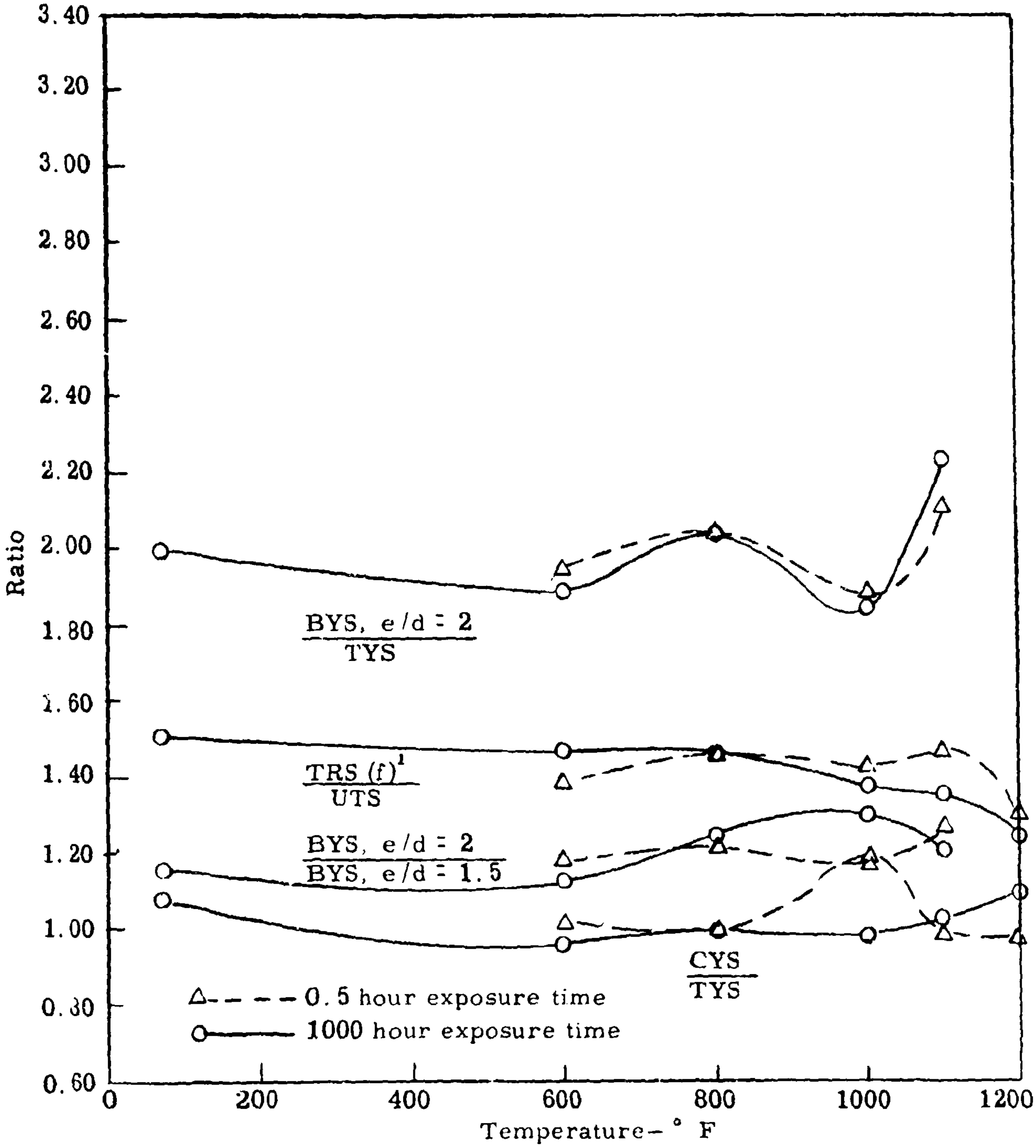


Fig. 141. Effect of temperature on four ratio relationships of properties of quenched and tempered A -286 austenitic alloy sheet.

1. TRS (f)–Tensile rupture strength based on the final cross section

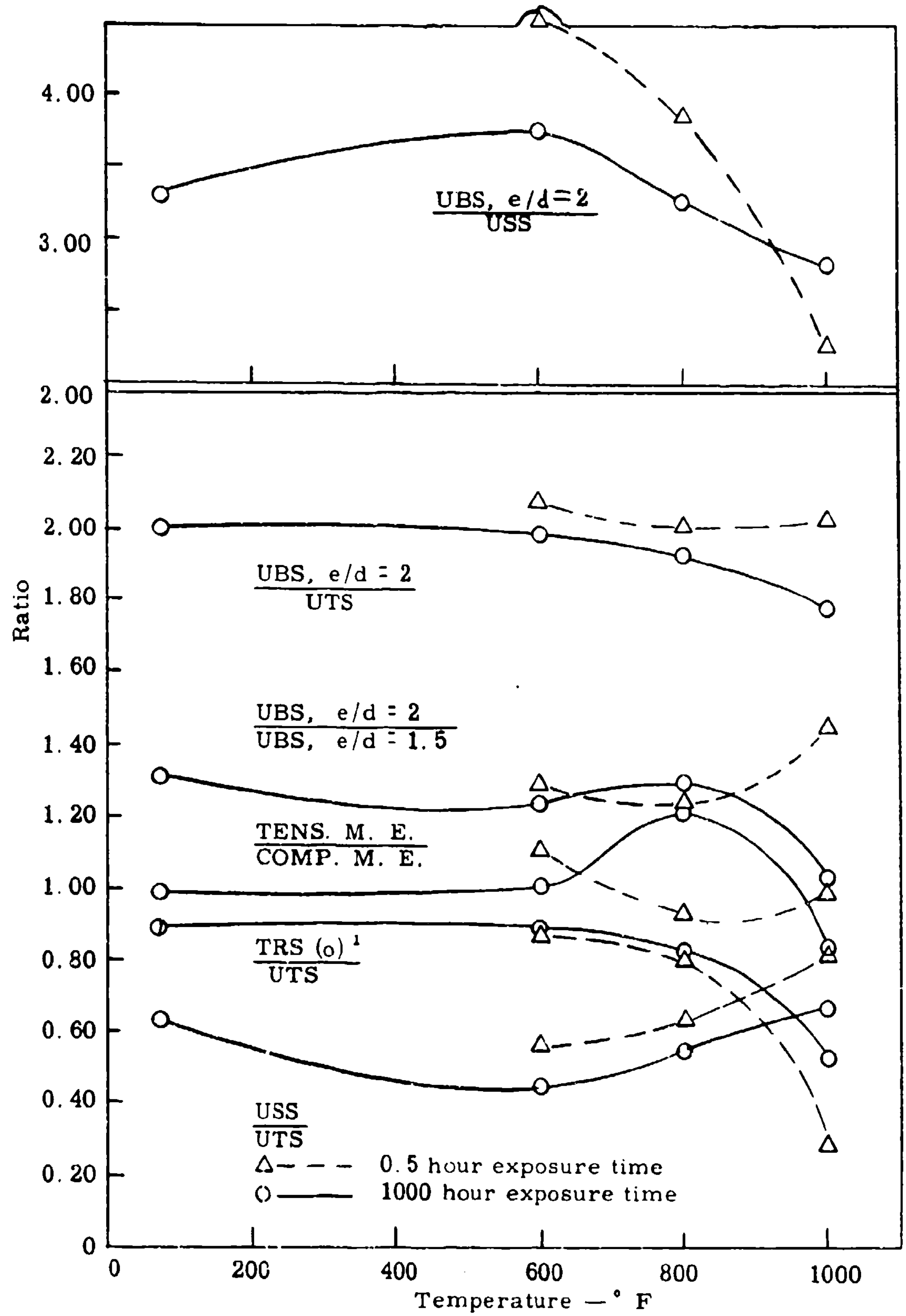


Fig. 142. Effect of temperature on six ratio relationships of properties of 17-7 PH (RH 950) stainless steel sheet.

1. TRS (o)—Tensile rupture strength based on the original cross section

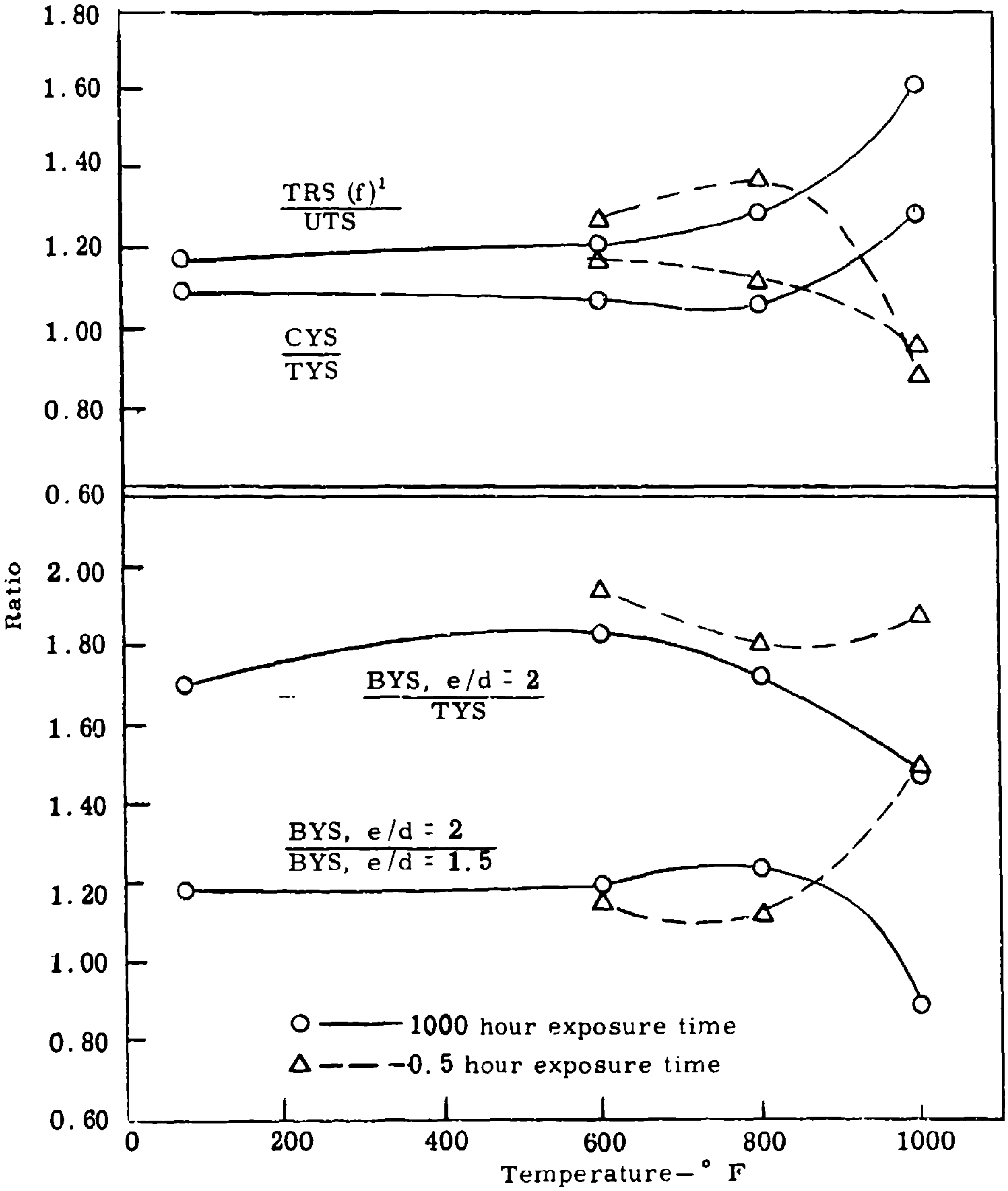


Fig. 143. Effect of temperature on four ratio relationships of properties of 17-7 PH (RH 950) stainless steel sheet.

1. TRS (f)-Tensile rupture strength based on the final cross sectio..

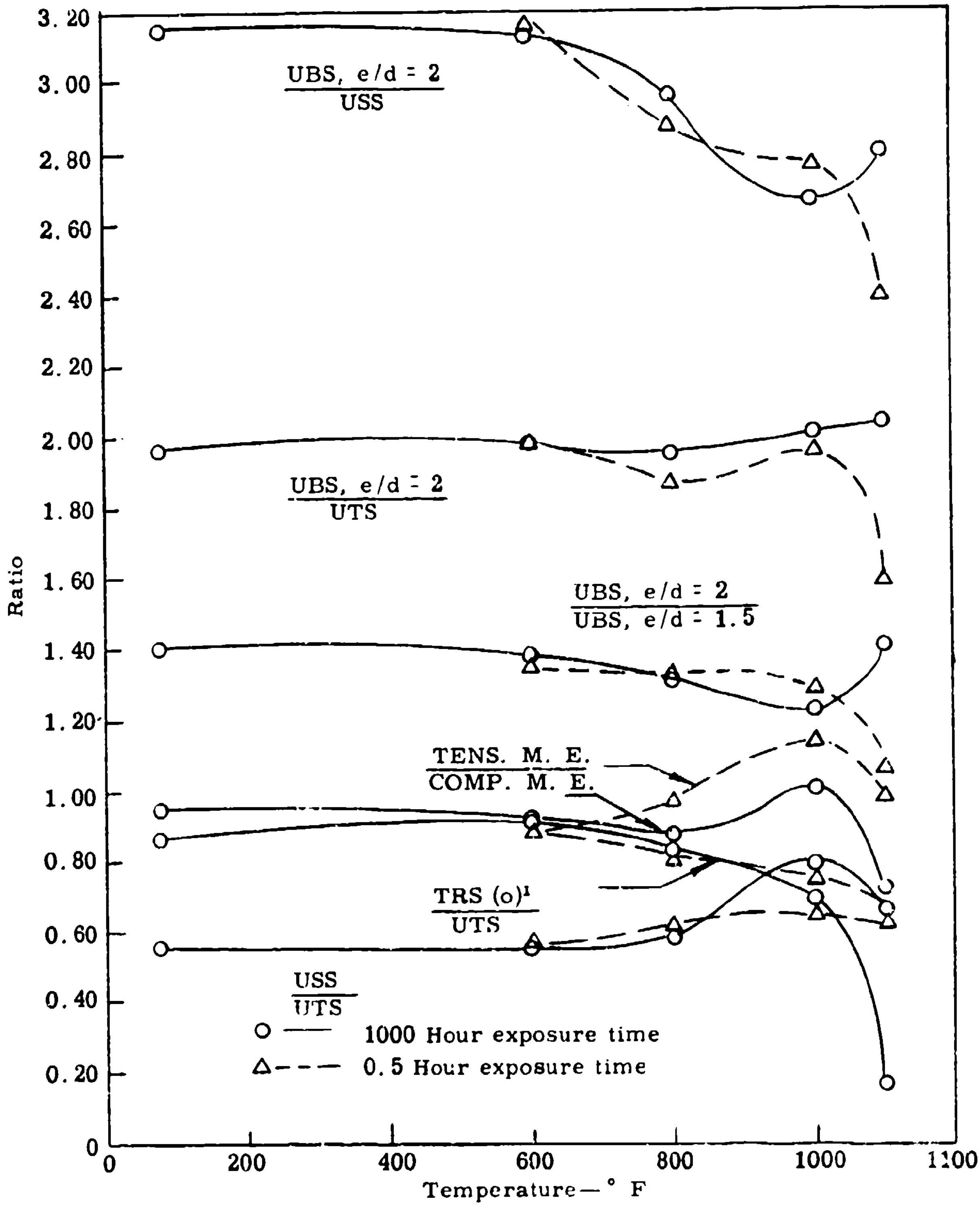


Fig. 144. Effect of temperature on six ratio relationships of properties of quenched and tempered Thermold J alloy steel sheet.

1. TRS (o)-Tensile rupture strength based on original cross section.

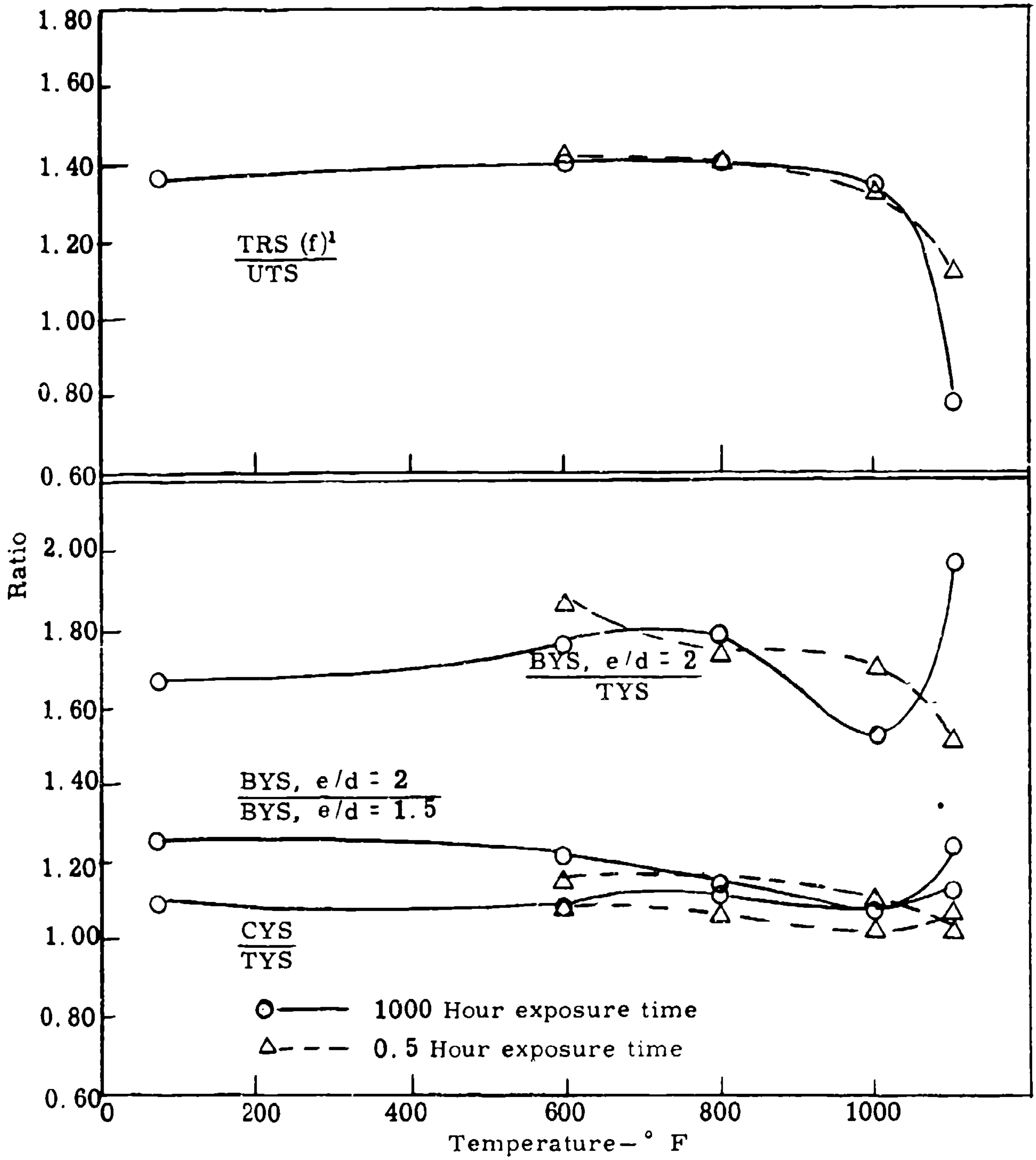


Fig. 145. Effect of temperature on four ratio relationships of properties of quenched and tempered Thermold J alloy steel sheet.

1. TRS (f)—Tensile rupture strength based on the final cross section

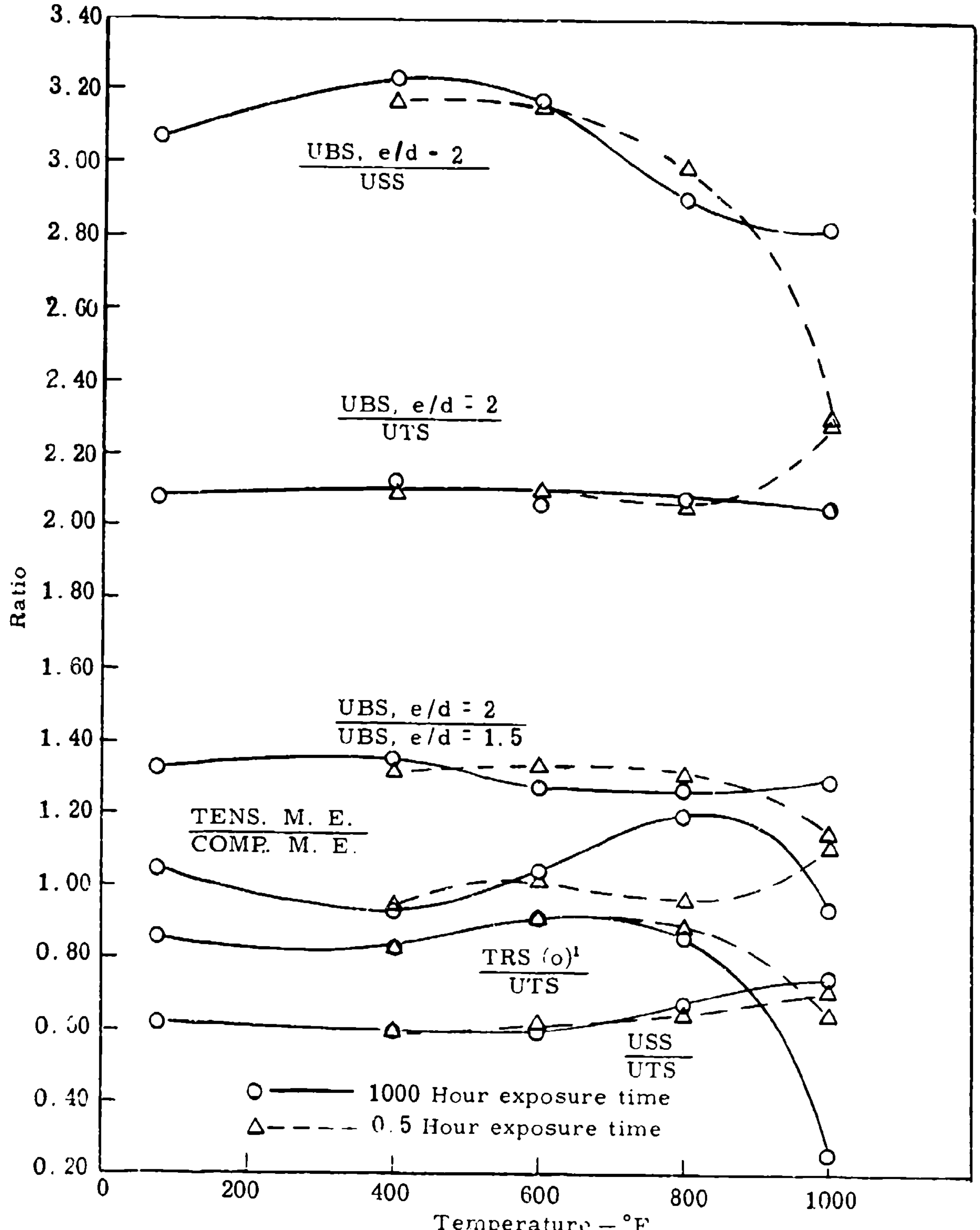


Fig. 146. Effect of temperature on six ratio relationships of properties of quenched and tempered Type 420 stainless steel sheet.

1. TRS (o)-Tensile rupture strength based on the original cross section

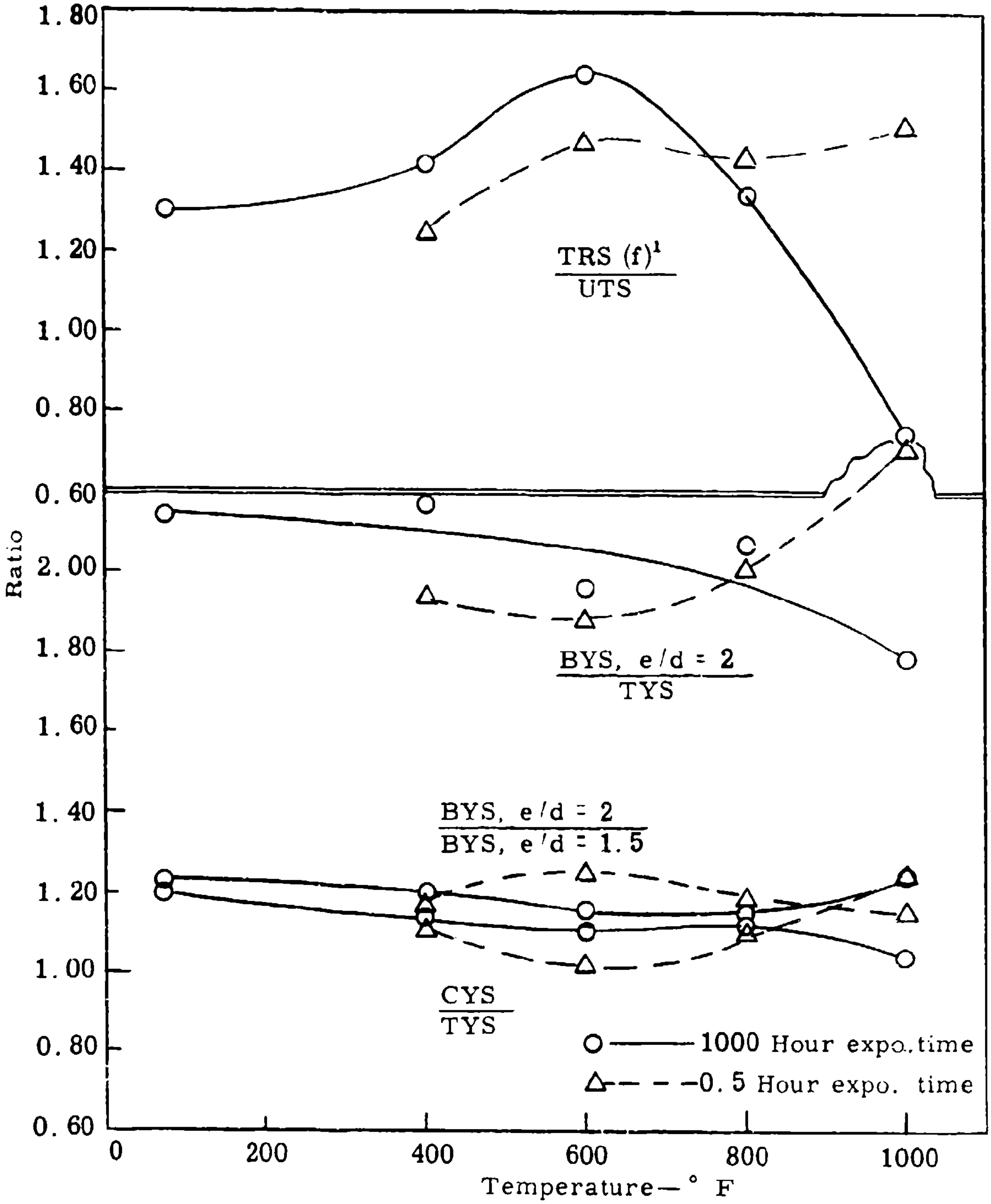


Fig. 147. Effect of temperature on four ratio relationships of properties of quenched and tempered Type 420 stainless steel sheet.

1. TRS (f)—Tensile rupture strength based on the final cross section

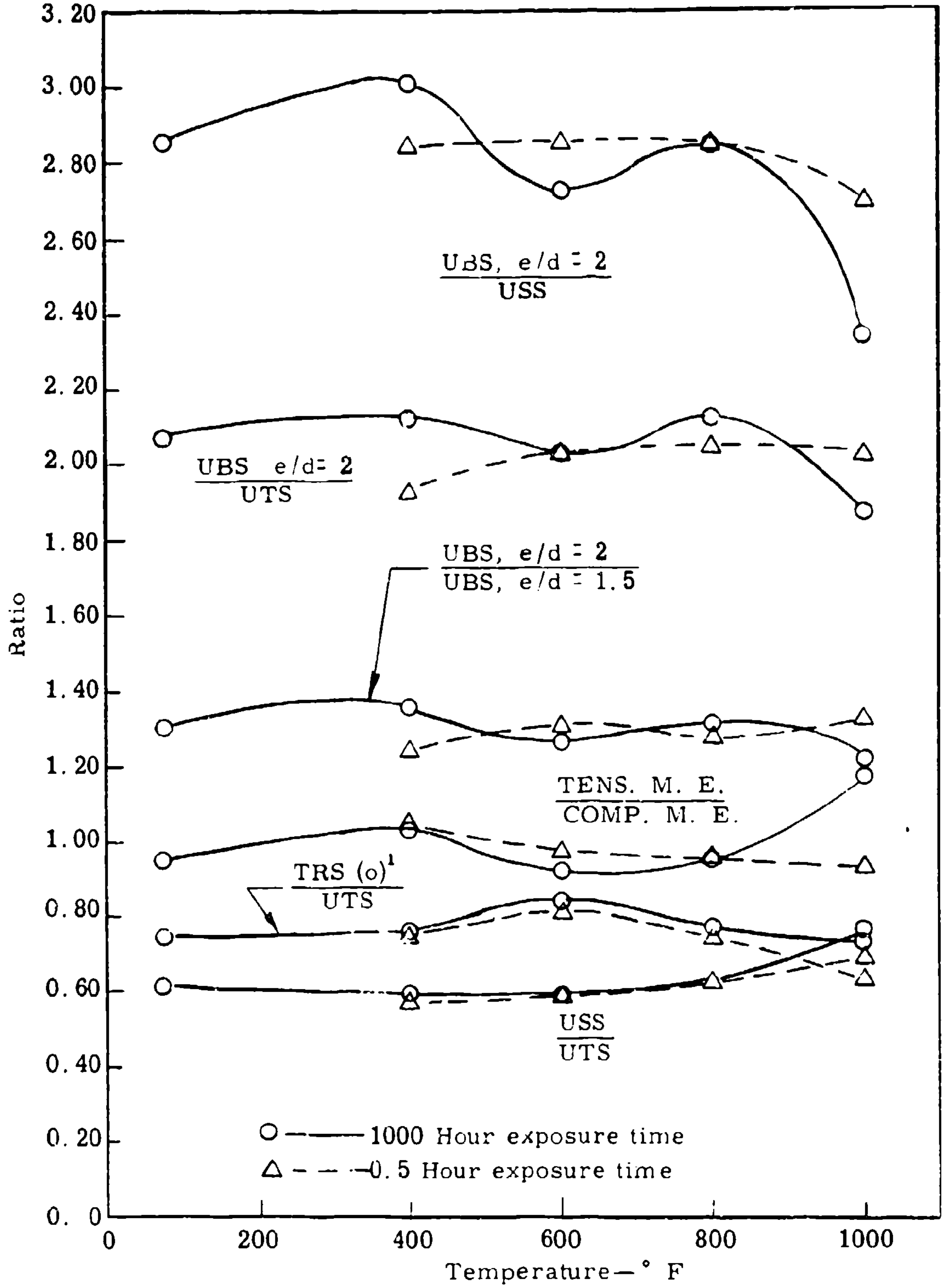


Fig. 148. Effect of temperature on six ratio relationships of properties of quenched and tempered Type 422 stainless steel sheet.

1. TRS (o)–Tensile rupture strength based on the original cross section

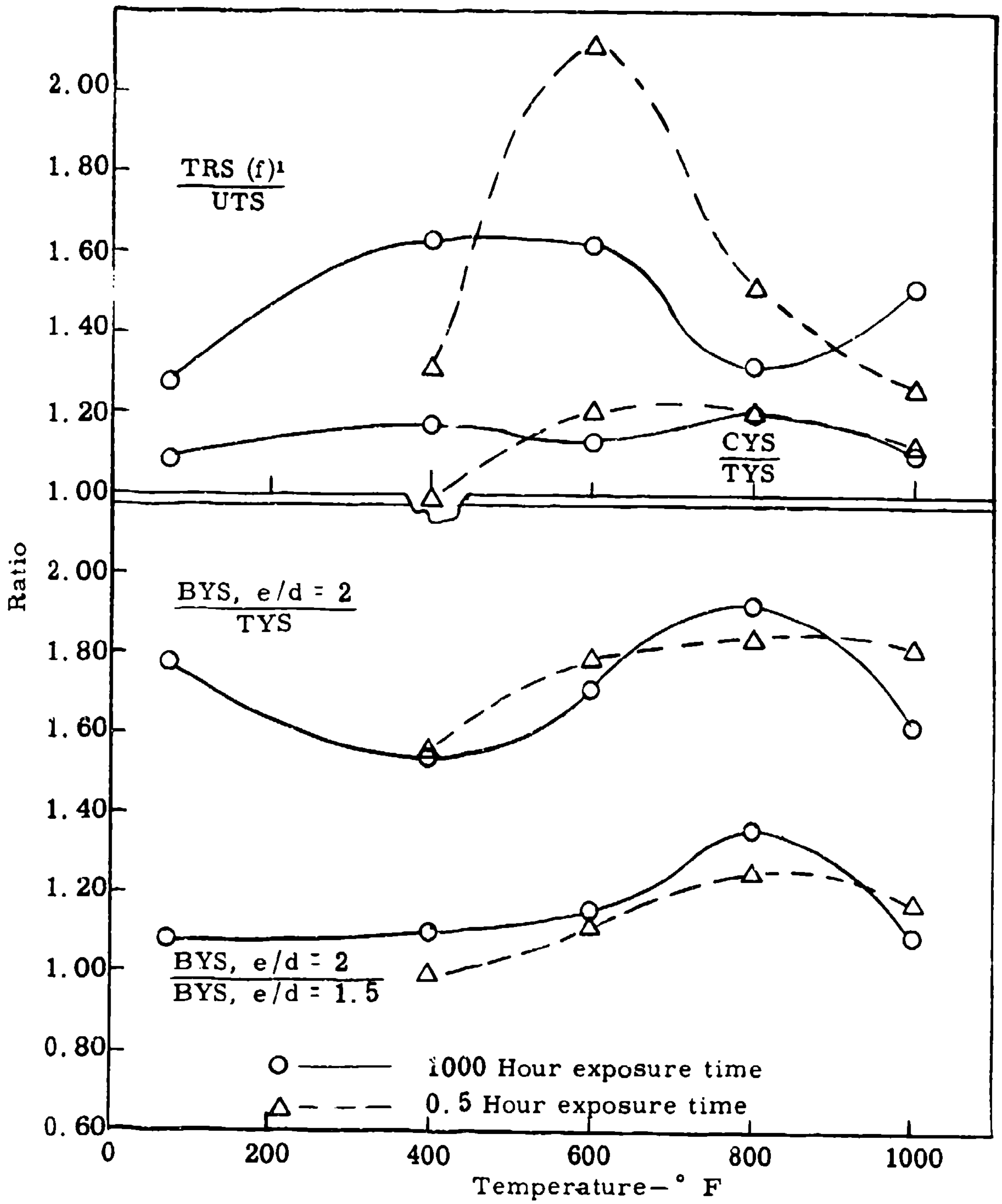


Fig. 149. Effect of temperature on four ratio relationships of properties of quenched and tempered Type 422 stainless steel sheet

1. TRS (f) Tensile rupture strength based on the final cross section

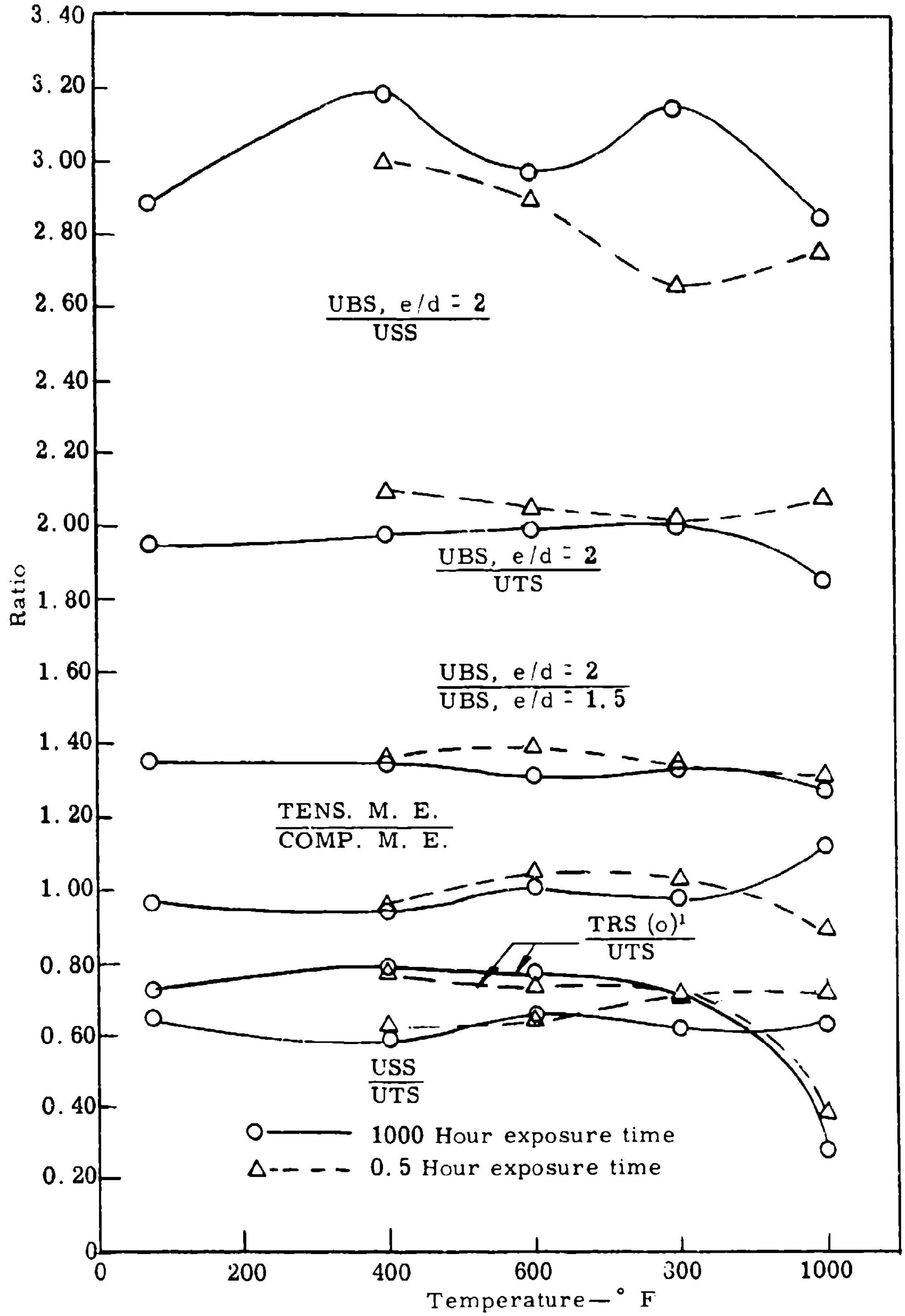


Fig. 150. Effect of temperature on six ratio relationships of properties of quenched and tempered 17-22 A (S) alloy steel sheet.

1. TRS (o) Tensile rupture strength based on the original cross section

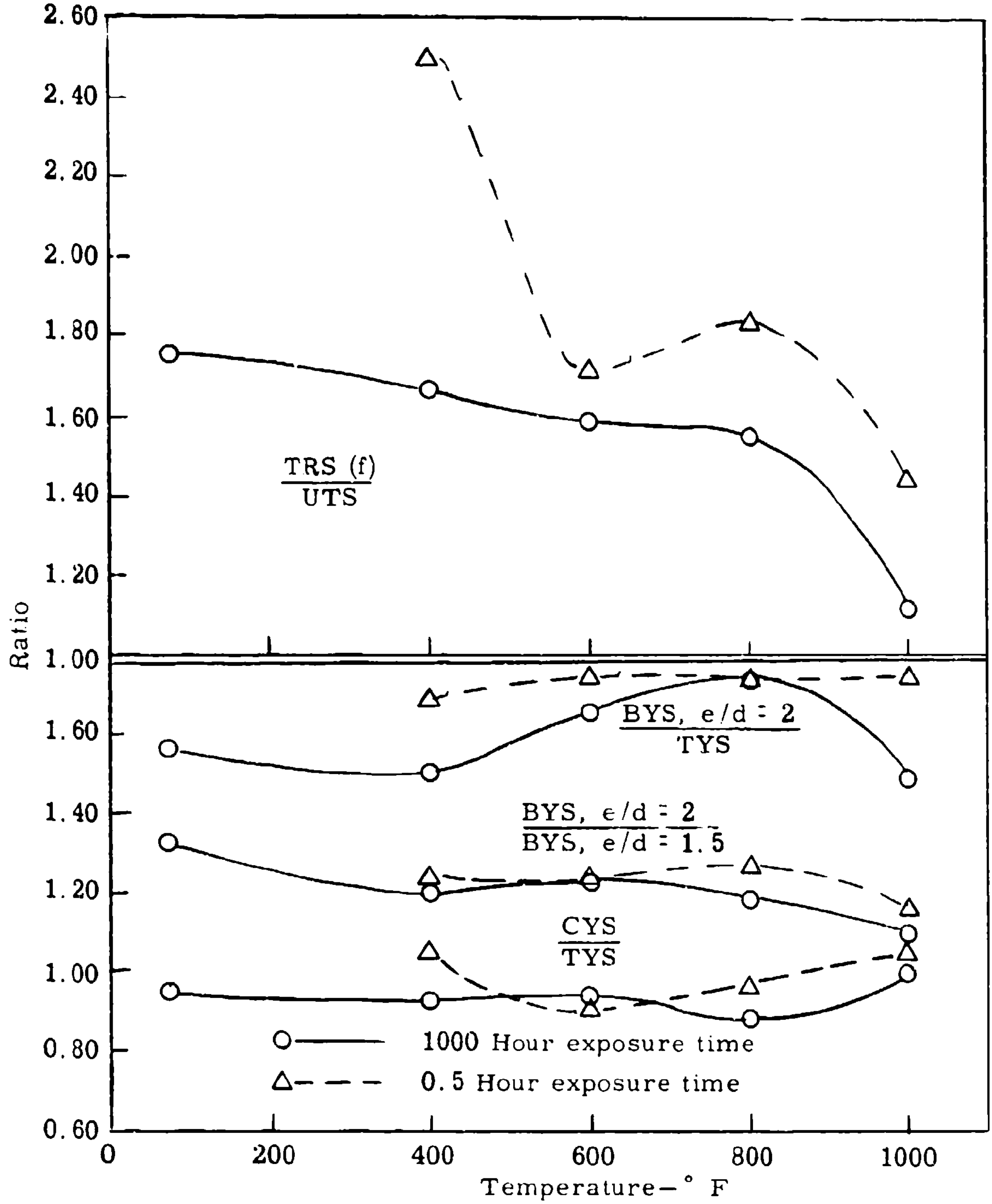


Fig. 151. Effect of temperature on four ratio relationships of properties of quenched and tempered 17-22 A (S) alloy steel sheet

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1. TRS (f) Tensile rupture strength based on the final cross section

Table 40

Ratio Relationships of Properties of Test Metals at Room Temperature

| Relationship | A-286 Alloy | 17-7 PH Stainless Steel | Thermold J Alloy Steel | Type 420 Stainless Steel | Type 422 Stainless Steel | 17-22 A (S) Alloy Steel |
|---|---|---|---|---|---|---|
| UBS[1], e/d=2 / USS[2] | 3.14 | 3.31 | 3.16 | 3.07 | 2.86 | 2.89 |
| UBS, e/d=2 / UTS[3] | 2.07 | 2.00 | 1.96 | 2.08 | 2.08 | 1.95 |
| UBS, e/d=2 / UBS, e/d=1.5 | 1.35 | 1.31 | 1.41 | 1.32 | 1.30 | 1.35 |
| Tensile M. E.[4] / Comp. M. E. | 0.97 | 0.99 | 0.96 | 1.04 | 0.95 | 0.96 |
| TRS[5] (o) / UTS | 0.92 | 0.89 | 0.87 | 0.86 | 0.74 | 0.72 |
| TRS[6] (f) / UTS | 1.60 | 1.18 | 1.37 | 1.30 | 1.28 | 1.76 |
| USS / UTS | 0.65 | 0.63 | 0.56 | 0.62 | 0.62 | 0.64 |
| BYS[7], e/d=2 / TYS[8] | 1.99 | 1.70 | 1.67 | 2.15 | 1.78 | 1.57 |
| BYS, e/d=2 / BYS, e/d=1.5 | 1.15 | 1.18 | 1.26 | 1.23 | 1.08 | 1.33 |
| CYS[9] / TYS | 1.08 | 1.09 | 1.10 | 1.20 | 1.08 | 0.95 |

1. Ultimate bearing strength
2. Ultimate shear strength
3. Ultimate tensile strength
4. Modulus of elasticity
5. Tensile rupture strength based on original cross-sectional area
6. Tensile rupture strength based on final cross-sectional area
7. Bearing yield strength
8. Tensile yield strength
9. Compressive yield strength

Table 41

Maximum and Minimum Ratio Relationships of Properties of Test Metals Over Range of Temperature[1] and Exposure Time[1]

| Relationship | | A-286 Alloy | 17-7 PH Stainless Steel | Thermold J Alloy Steel | Type 420 Stainless Steel | Type 422 Stainless Steel | 17-22 A (s) Alloy Steel | Combined Test Results |
|---|---|---|---|---|---|---|---|---|
| UBS[2] e/d = 2 / USS[3] | Max | 3.14 | 4.52 | 3.18 | 3.23 | 3.01 | 3.19 | 4.52 |
| | Min | 2.95 | 2.26 | 2.40 | 2.30 | 2.34 | 2.66 | 2.26 |
| UBS, e/d = 2 / UTS[4] | Max | 2.10 | 2.07 | 2.05 | 2.29 | 2.13 | 2.10 | 2.29 |
| | Min | 1.91 | 1.78 | 1.60 | 2.06 | 1.88 | 1.86 | 1.60 |
| UBS, e/d = 2 / UBS, e/d = 1.5 | Max | 1.37 | 1.45 | 1.42 | 1.36 | 1.36 | 1.39 | 1.45 |
| | Min | 1.26 | 1.03 | 1.07 | 1.16 | 1.22 | 1.28 | 1.03 |
| Tensile. M.E.[5] / Comp. M.E. | Max | 1.30 | 1.21 | 0.99 | 1.20 | 1.18 | 1.12 | 1.30 |
| | Min | 0.85 | 0.84 | 0.70 | 0.93 | 0.93 | 0.89 | 0.70 |
| TRS[6] (o) / UTS | Max | 0.94 | 0.89 | 0.92 | 0.92 | 0.84 | 0.79 | 0.94 |
| | Min | 0.86 | 0.29 | 0.17 | 0.26 | 0.73 | 0.28 | 0.17 |
| TRS[7] (f) / UTS | Max | 1.51 | 1.62 | 1.42 | 1.51 | 2.11 | 2.50 | 2.50 |
| | Min | 1.26 | 0.88 | 0.80 | 0.74 | 1.26 | 1.12 | 0.74 |
| USS / UTS | Max | 0.72 | 0.81 | 0.80 | 0.75 | 0.76 | 0.71 | 0.81 |
| | Min | 0.58 | 0.44 | 0.56 | 0.60 | 0.57 | 0.59 | 0.44 |
| BYS[8], e/d = 2 / TYS[9] | Max | 2.23 | 1.94 | 1.98 | 2.32 | 1.92 | 1.75 | 2.32 |
| | Min | 1.84 | 1.47 | 1.52 | 1.79 | 1.54 | 1.49 | 1.47 |

Table 41 (continued)

Maximum and Minimum Ratio Relationships of Properties of Test Metals Over Range of Temperature[1] and Exposure Time[1]

| Relationship | | Metal | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | A-286 Alloy | 17-7 PH Stainless Steel | Thermold J Alloy Steel | Type 420 Stainless Steel | Type 422 Stainless Steel | 17-22 A (S) Alloy Steel | Combined Test Results |
| BYS, e/d = 2 / BYS, e/d = 1.5 | Max | 1.30 | 1.50 | 1.14 | 1.24 | 1.36 | 1.33 | 1.50 |
| | Min | 1.13 | 0.89 | 1.02 | 1.15 | 1.00 | 1.11 | 0.89 |
| CYS[10] / TYS | Max | 1.18 | 1.30 | 1.26 | 1.25 | 1.21 | 1.06 | 1.30 |
| | Min | 0.97 | 0.96 | 1.03 | 1.02 | 0.99 | 0.89 | 0.89 |

1. Room temperature to 1200° F for A-286, to 1100° F for Thermold J, and to 1000° F for other materials; exposure times 1/2 hour and 1000 hr.
2. Ultimate bearing strength
3. Ultimate shear strength
4. Ultimate tensile strength
5. Modulus of elasticity
6. Tensile rupture strength based on original cross-sectional area
7. Tensile rupture strength based on final cross-sectional area
8. Bearing yield strength
9. Tensile yield strength
10. Compressive yield strength